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CONTRACT TRIAL OF THE UNITED STATES SEAGOING BATTLESHIP *ILLINOIS.*

BY LIEUTENANT JAMES M. PICKRELL, U. S. NAVY.

The *Illinois* is a twin-screw, armored, seagoing battleship, and was built by the Newport News Shipbuilding and Dry Dock Company, of Newport News, Va. The Navy Department furnished the general plans and specifications for hull and machinery to the contractors and builders, and the latter developed the general designs into exact details, together with the piping systems and location of the auxiliary machinery, submitting their drawings for approval to the bureaus concerned before work was begun. The contract was signed September 26, 1896, the price being $2,595,000, and the time allowed for completion three years. The price stated above does not include the armor (exclusive of that required in the construction of the protective deck), the armor bolts, the ordnance, the ordnance outfit, and certain articles, as anchors and chains, supplied by the Government, but does include the fitting and installation of the above. The speed guarantee was 16 knots per hour, to be maintained

successfully for four consecutive hours, during which period the air pressure in the fire rooms was not to exceed an average of one inch of water; the vessel to be weighted to a mean draught of 23 feet 6 inches. No premium for speed in excess of that required by the contract was provided for, but a penalty was inflicted at the rate of $25,000 per ¼ knot between 16 and 15½ knots, and $50,000 per ¼ knot between 15½ and 15 knots, but if the speed should fall below 15 knots it was optional with the Secretary of the Navy to reject the vessel or accept her at a reduced price. The weight of the machinery was limited to 1,130 tons, which weight included main engines, boilers and appurtenances, distilling apparatus, tools in workshop, and water in boilers, condensers, pumps, pipes and stern tubes, but did not include turret machinery, capstan, windlass, steering gear or winches. The penalty for over weight was $500 per ton up to 5 per cent., beyond which an additional $10,000 was to be attached.

HULL.

Length between perpendiculars, feet	368
on L.W.L., feet and inches	368– 1½
over all (including rudder), feet and inches	375– 4½
Beam, extreme, feet and inches	72– 2½
at L.W.L, feet and inches	72– 2½
Ratio of length to beam	5.20
Depth (molded) from top of main-deck beams at side to bottom of frames at M.S., feet and inches	34– 6
Height of superstructure above main-deck beams to bridge deck, feet and inches	25–11⅞
Draught, normal, forward, feet and inches	23– 7⅞
aft, feet and inches	23– 7⅞
mean, feet and inches	23– 7⅞
Displacement, corresponding to normal draught, tons	11,625
per inch, at L.W.L., tons	47.85
Area of immersed midship section to L.W.L., square feet	1,620
L.W.L. plane, square feet	20,120
Center of gravity of L.W.L. plane, aft of M.S., feet	2.1
buoyancy above bottom of keel, feet	12.95
forward of M.S., feet	1.02
gravity above bottom of keel, feet and inches	25– 0½
Transverse metacenter above center of buoyancy, feet	16.95
Longitudinal metacenter above center of buoyancy, feet	370

Coefficient of fineness on extreme dimensions	.644
of midship section	·957
L.W.L.	·759
Cylindrical coefficient	.682
Number of frames	94
watertight compartments	309

The hull is constructed of mild steel of domestic manufacture with frames spaced 4 feet apart, except when intermediate frames are required, from the stem to frame No. 76; and from this point aft the frames are spaced 3 feet 6 inches apart. The ship is divided into 309 watertight compartments. The double bottom extends from frame No. 22 to frame No. 75, and runs up to the 5th longitudinal from 31 to 66, and to the 4th longitudinal from 22 to 31 and from 66 to 75. A cofferdam 36 inches wide is constructed between the berth and the protective decks on each side of the vessel, extending from the transverse armor bulkheads to the extremities of the vessel. On the berth deck a cofferdam 36 inches above the deck and 3 feet wide is worked on each side between frames No. 11 and No. 79, except where the torpedo tubes are fitted. The cofferdams are filled with fire-proofed corn-pith cellulose packed to a density of 6 pounds per cubic foot. All the wood used in the construction of the vessel is fire-proofed, and the use of the wood at all is avoided wherever practicable. The upper deck and the main deck, outside of the superstructure, are the only ones laid with wood, the others being covered with linoleum.

Main Deck.—On the main deck is located the 6-inch battery in broadside, fitted within the superstructure in stalls formed by splinter bulkheads; on this deck are also located the crew's W. C. and the showers, ordnance and pay offices, bakery, drying room, junior officers' mess room, pantry, wardroom, junior and warrant officers' W. C. and the armory. It also forms the principal part of the crew's messing and berthing space.

Berth Deck.—On this deck are situated the quarters of the admiral, captain and officers, and a berthing space for a part of the crew, and in addition the ice machine and refrigerating rooms, the sick bay and dispensary, torpedo rooms, lavatories and coal bunkers above protective deck. On the protective

deck are fresh-water tanks, store rooms, and a small berthing compartment.

Splinter and Platform Decks and Hold.—Below the protective deck are the machinery spaces, dynamo room, coal bunkers, holds, chain lockers, trimming tanks, store rooms, magazines, shell rooms, blower rooms, central station for communications, steering gear, engineers' and ordnance workshops, air compressors and ammunition hoists.

There are thirty-two coal bunkers with a total capacity of 1,270 tons at 43 cubic feet to the ton. They are distributed as follows: Ten on the berth deck with a capacity of 224 tons, eight on the splinter deck with a capacity of 115 tons, and fourteen in the hold with a capacity of 931 tons. They are filled from either the upper or the main deck through portable chutes and trunks fitted between decks. The trunks have shunt doors fitted at the tops where they pass through the bunkers on the berth deck, and vertical doors at the bottom, for passing the coal from the upper to the lower bunkers. Armored shutters are fitted in the trunks where they pass through the protective deck. Trolley rails and buckets are fitted fore and aft in the hold bunkers, with portable sections in the wake of watertight doors, for the transportation of the coal. Escape doors are fitted to all the bunkers on the berth deck open on the main deck (circular plates), those on the splinter deck to ammunition passage (swinging doors), and those in the hold to deck of ammunition passage (circular plates). Steam fire-extinguishing pipes are fitted to all the bunkers and holds. Over the vertical watertight sliding doors of the hold bunkers are fitted screen doors, in the shape of a hood, designed to take the weight of the coal from the watertight doors, so that they may be easily closed at any time.

There are two ash chutes on each side fitted inside the vessel. The upper ends of the chutes extend above the main deck, where hoppers are formed inside, and so arranged that the fire-main pressure may be used to clear the chute. Trolley ways for carrying the ash buckets are fitted under the deck beams above, leading from the ash hoists to the chutes.

The following list of capacity of each coal bunker is given.

Compartment.		Capacity.	
		Cubic feet.	*Tons.*
		Hold and Platform Deck.	
	B- 7	3,698	86
	B- 8	3,741	87
	B-11	3,526	82
	B-12	3,526	82
	B-15	3,612	84
	B-16	3,612	84
	B-21	3,053	71
	B-22	3,010	70
	B-23	3,569	83
	B-24	3,569	83
	C- 3	1,419	33
	C- 4	1,419	33
	C- 7	1,118	26
	C- 8	1,161	27
Total,	14	40,033	931
		Splinter Deck.	
	B-33	602	14
	B-34	559	13
	B-49	688	16
	B-50	688	16
	C-13	645	15
	C-14	645	15
	C-17	559	13
	C-18	559	13
Total,	8	4,945	115
		Berth Deck.	
	B-102	860	20
	B-103	860	20
	B-110	1,032	24
	B-111	1,032	24
	B-115	1,247	29
	B-116	1,247	29
	B-123	1,118	26
	B-124	1,118	26
	C-100	559	13
	C-101	559	13
Total,	10	9,632	224

Drainage System.—The main drain pipe is of galvanized steel, 14 inches in diameter, and runs from the forward boiler rooms along the port side of the center-line bulkhead above the inner bottom to the engine rooms, having branches connecting it with the starboard compartments. It is fitted with stop check valves in each boiler and engine room, all worked from the berth deck. The suction pipes leading from the valves in the boiler rooms do not dip into drainage wells, but have their mouths located as low down as practicable and covered with coarse strainers. The main drain pipe leads to the main circulating pumps, and is also provided with connections to the principal steam pumps other than the main feed pumps and water service pumps.

For the auxiliary drainage system, manifolds are fitted in convenient locations throughout the machinery space, with suction pipes leading to the double-bottom compartments, trimming tanks, and principal lower compartments of the ship, and to the sea connections as required. Where these pipes drain water from compartments above the inner bottom a small well is fitted projecting 6 inches into the inner bottom and covered by a plate strainer. All manifold valves are worked from the manifolds only. A 5-inch drain connects the forward and the after manifold, with flanges for the pump connections. In the boiler and the engine compartments the suctions are fitted with flanges for a direct connection to the pumps in that compartment, and the crank pits are drained independently of the remainder of the bilge. The compartments above the protective deck are drained by scuppers or portable pumps. The small store rooms below the protective deck are drained by portable pumps, and the coal bunkers below the protective deck by their own vertical sliding doors. The waste water from the bath and wash rooms is led by pipes to two tanks located in the forward part of the engineer's workshop, and is pumped overboard by an ejector.

ARMOR.

The armor consists of a side belt of Harveyized nickel-steel extending 3 feet 6 inches above and 4 feet below the 23½-foot load line. The thickness amidships of the side belt is 16½ inches

at the top, and 9½ inches at the top of the armor shelf. The maximum thickness of armor at the water line is maintained from the center line of the after barbettes, where the belt begins, to the forward coal bunker bulkhead, tapering to 10½ inches to the center line of forward barbettes, thence to 4 inches in a distance of 30 feet, which thickness is maintained to the bow of the vessel. The triangular armor extends from the slopes of the protective deck to the top of the armor belt at the forward and after ends of the machinery spaces, 12 inches in thickness. Above the side belt is a casemate 5½ inches thick, worked from the center line of the forward barbette to the center line of the after barbette. The ends of the belt are formed by the diagonal armor, 5½ inches thick, worked from the sides of the vessel to the barbette armor. The thickness of the superstructure armor is 5½ inches. The protective deck between armor bulkheads is 2¾ inches thick, and at the extremities, on the side slopes, are fitted plates of armor 3 inches thick forward and 4 inches thick aft. The splinter bulkheads between the 6-inch gun stations are each one piece of plate 60 pounds per square foot. The armor in front of the 6-inch guns on the upper deck amidship and main deck forward is 6 inches thick.

The barbettes are 15 inches thick at the front and 10 inches thick at the rear; the 13-inch turrets are 14 inches thick. The forward conning tower is eliptical in shape, and is 10 inches thick, the after conning tower or signal station is 6 feet in diameter and 6 inches thick. An armor tube 7 inches thick is fitted between the base of the conning tower and the protective deck, to afford protection to the voice pipes, electric wires, engine telegraphs, steering gear and engine tell-tales.

ARMAMENT.

The main battery consists of four 13-inch breech-loading rifles, 35 calibers, mounted in pairs, in two balanced turrets, on the fore-and-aft center line of the ship, and fourteen 6-inch rapid-fire breech-loading rifles, 40 calibers, mounted ten on the main deck and four on the upper deck.

The secondary battery consists of sixteen 6-pounder rapid-fire

guns, six 1-pounder rapid-fire guns, four of which are automatic, eight .30-caliber Colt automatic machine guns, and two 3-inch field guns. There are four tubes for Whitehead torpedoes, two on each side, discharging directly from the berth deck. The turrets are trained by electricity, and the 13-inch guns are elevated and loaded by the same power. The 6-inch guns are worked by hand on central-pivot carriages.

The boats carried are as follows:

One 36-foot steam cutter; one 33-foot steam cutter; two 33-foot sailing launches; five 30-foot cutters; two 30-foot whale boats; one 30-foot gig; one 30-foot barge; two 20-foot dinghies; two 18-foot balsas; two 12-foot punts.

MAIN ENGINES.

There are two three-cylinder triple-expansion engines of the vertical, inverted, direct-acting type, placed abreast of each other in separate watertight compartments, the H.P. cylinders being forward. The engine framing consists of twelve wrought-steel, cylindrical columns, well trussed and stayed diagonally, fore-and-aft and athwartship; in addition, the H.P. and L.P. cylinders of one engine are secured to the corresponding cylinders of the other, the rod passing through a stuffing box in the center-line bulkhead; also the high and low-pressure cylinders are secured longitudinally to the athwartship bulkheads. The valves are all of the single-ported piston type, there being one for each high-pressure cylinder, two for each intermediate and four for each low-pressure cylinder. The link motion is of the double-bar Stephenson type, and the valve gears of the three cylinders are interchangeable. Independent adjustable cut-off blocks are fitted to each link, with a range from .5 to .7 of the stroke. The main valves are provided with balance pistons, the cylinders of which form part of the upper covers of the valve chests. There are no starting valves on the cylinders, provision being made for starting the engines by admitting live steam to the receivers. The high-pressure cylinder is steam jacketed around the working linings, and the intermediate and the low-pressure cylinders are steam jacketed around the working linings and at both ends.

Each engine is fitted with a double-disc, balanced, stop and throttle valve, worked by a lever and adjusted by a screw stem and hand wheel from the working platform. The main steam pipes are of copper, and where above 9½ inches in internal diameter are strengthened with steel bands spaced 6 inches between centers. In the starboard engine room there is a 50-gallon distributing oil tank for supplying the oil manifolds of both engines. This tank is supplied from the main tanks by a Worthington duplex steam pump, and by a hand pump, and can be used as either a pressure or a gravity tank.

The main pistons are steel castings, dished, and are each fitted with two packing rings and a follower. The piston rods are of forged nickel-steel, oil tempered, and hollow, the outside diameter being 7½ inches and the inside diameter 3½ inches; a screw plug is fitted and riveted over at the upper end. The connecting rods, with their caps and bolts, are of forged nickel-steel, oil tempered; the rods have a 4½-inch axial hole bored through their entire length. The body of the crosshead is forged on the end of the piston rod, and a manganese-bronze slipper, whose sliding faces are fitted with white metal, is bolted to its under side. The crosshead guides are of cast iron, and are made hollow for the circulation of water to keep them cool. At the top they are bolted to lugs cast on the cylinder casings, and at the bottom to forged-steel cross bars, secured to the engine columns. The backing guides are also of cast iron, and are bolted to flanges provided for that purpose on the go-ahead guides. The eccentrics are of cast iron. Each backing eccentric is securely keyed on the shaft, and each go-ahead eccentric is secured to the corresponding backing one by through bolts in slotted holes. The eccentric straps are of composition, faced with white metal, and the eccentric rods of forged steel. The I.P. and L.P. valve stems have cast-steel crossheads which take hold of the link blocks directly. Each engine bedplate consists of three sections of steel castings.

There is a steam float-lever reversing gear, with a hydraulic controlling cylinder, which can also be adjusted to work by a hand pump, there being a common piston rod for both steam and water pistons.

The turning engine is a double, inverted, simple, 7 by 5 engine, operating a worm shaft, which in turn operates a second worm shaft and gear made to readily engage in a worm wheel secured on the forward end of the low-pressure section of crank shaft. The turning-engine shaft is squared at the end and fitted with a ratchet wrench for turning by hand.

ENGINE DATA.

Cylinders, number for each engine	3
H.P., diameter, inches	33½
I.P., diameter, inches	51
L.P., diameter, inches	78
Stroke of piston, inches	48
Valves, H.P. (one for each cylinder), diameter, inches	19½
L.P. (two for each cylinder), diameter, inches	18
Balance pistons, H.P., diameter, inches	6
I.P., diameter, inches	7½
L.P., diameter, inches	7½
Valve stems, H.P. (1), diameter, inches	2⅜
H.P. (1), diameter through valve, inches	1⅞
I.P. (2), diameter, inches	2¾
I.P. (2), diameter through valve, inches	1⅞
L.P. (4), diameter, inches	2¾
L.P. (4), diameter through valve, inches	1⅞
Main steam pipe (13 inches diameter), area cross section, square inches	132.73
Exhaust pipes to I.P. cylinder, (1) 17 inches H.P. end, 17 inches I.P. end, area of cross section, square inches	226.86
L.P. cylinder, (4) 15 inches I.P. end, (8) 11 inches	706.50
L.P. end, area of cross section, square inches	759.88
condenser, (2) 19 inches diameter, area of combined cross section, square inches	566.77
Volume swept by H.P. piston (mean), per stroke, cubic feet	23.84
I.P. piston (mean), per stroke, cubic feet	56.09
L.P. piston (mean), per stroke, cubic feet	132.04
Net area of I.P. to H.P. piston	2.34
L.P. to I.P. piston	2.36
L.P. to H.P. piston	5.53
Clearances of H.P. cylinders, per cent.....top, 18.9; bottom,	22.8
I.P. cylinders, per cent.....top, 18.9; bottom,	24.7
L.P. cylinders, per cent.....top, 17.5; bottom,	22.9
Piston rods, diameter, inches	7½
length from piston to crosshead, feet and inches	6– 6⅛
Connecting rods, length from center to center, feet	8
diameter of upper end, inches	7⅞
lower end, inches	8¼

Connecting rods, crosshead bolts (2), diameter, inches	4¼
crank pin bolts (2), diameter, inches	4¼
Crossheads, surface (ahead), square inches	459
(backing), square inches	357
pins, diameter, inches	9¾
length, inches	14
Reversing gear, steam cylinder, diameter, inches	15
controlling cylinder, diameter, inches	7½
Crank shafts, diameter, inches	14¾
axial hole, inches	7½
coupling discs, diameter, inches	29
thickness, inches	3½
bolts in one flange (6), diameter, inches	3½
journals, diameter, inches	14¾
length, inches	16½
length of each section, feet and inches	8–10
Crank pins, diameter, inches	14¾
length, inches	17
axial hole, inches	7½
Crank webs, width, inches	16½
thickness, inches	10
Thrust shaft, diameter, inches	14
of coupling disc, inches	29
axial hole, inches	9
collars, number each shaft	11
diameter, inches	21½
thickness, inches	2
distance between, inches	3½
surface, total for both engines, square inches	4,600.64
length, feet and inches	15– 5½
Line shafts, diameter, inches	14
axial hole, inches	9
diameter of coupling discs, inches	29
length, feet and inches	31–10⅛
Propeller shafts, diameter, inches	14¾
axial hole, inches	9¾
Propeller shafts, outboard, length, feet and inches	26– 5½
coupling, diameter, inches	21
length, feet and inches	4– 8½
inboard, length, feet and inches	31–10
Stern bracket bearing, length, inches	48½
diameter, inches	16⅛
tube bearing, length, forward, inches	40¾
aft, inches	42

Shafting and Bearings.—The crank shafts are of forged steel,

and for each engine are made in three interchangeable and reversible sections, the cranks being 120 degrees apart, and for the ahead motion follow in the order H.P., I.P. and L.P. There is a 7½-inch axial hole through crank shaft and pin. The line, thrust and propeller shafting is hollow and of forged nickel-steel. The propeller shafts are fitted with a composition casing from inboard of the stern-tube stuffing box to the propeller hub. The propeller shaft is in two sections connected by an outboard sleeve coupling fitted near the after end of the stern tube, and protected by a watertight covering. The thrust bearings are of the horseshoe pattern; the pedestals are of cast iron, the ends and side walls forming an oil trough; at each end there is a bearing, lined with white metal, for taking the weight of the shaft. The horseshoes are eleven in number, and are of cast steel, faced with white metal, and fitted with oil cups and holes for the distribution of oil to the bearings. At each end of the bearing there is a divided stuffing box and gland to prevent the escape of the oil. The pedestal is bolted to a cast-iron sole plate, fitted with wrought-iron wedges at each end of the pedestal for adjusting the bearings fore and aft.

Main Condensers.—There are two main condensers, one for each engine; the shells are of wrought-steel plate, with an angle iron riveted around each end forming a flange for securing the water chests. The water chests and tube sheets are of composition. The circulating water passes through the tubes. Baffle, circulating and tube-supporting plates are fitted. There are by-pass valves in the water chests to allow the water from the circulating pumps to pass directly overboard.

Diameter of shell (inside), feet and inches	5– 8½
Thickness of shell, inch	1⅝
Length over heads, feet and inches	13– 4
Tubes, diameter (outside), inch	⅝
length between tube sheets, feet and inches	11– 6
thickness, No. 18 B.W.G., inch	.049
number in each condenser	3,749
Cooling surface, each condenser, square feet	17,050
Total cooling surface, square feet	14,100
Ratio of total cooling to total heating surface	1 to 1.56

Main Air Pumps.—For each engine there is a Worthington twin-cylinder, vertical, single-acting air pump. The steam cylinders are placed directly over the pump cylinders, the pump rods and piston rods forming a continuous length. The pumps are connected by means of a beam which is pivoted at its center, and from which beam the valve motion is actuated. The beam receives its motion through links swinging from crossheads on the pump and piston rods. The pump valves are each made of three flat discs of rolled manganese-bronze.

Diameter of steam cylinders (2), inches	12
pump cylinders (2), inches	25
Stroke, inches	18
Diameter of piston rods, inches	$2\frac{7}{16}$
pump rods, inches	$2\frac{3}{4}$
pump valves, inches	3, 4, $4\frac{1}{8}$
Ratio of volume swept by L.P. piston, net area, per stroke, to that of the two air-pump buckets, per stroke	13

Main Circulating Pumps.—For each condenser there is a centrifugal, double-inlet, circulating pump, which is arranged to draw from the sea, the bilge and the main drain pipe, and to discharge either into the condenser or directly overboard. The sea and the bilge injection valves are fitted with a self-locking arrangement so that both cannot be operated at the same time. One of these pumps was tested under conditions assimilated to that of drawing water from the bilge and discharging directly overboard, the length and size of the piping and the head at discharge being the same as would occur in actual service. The velocity at discharge was measured by a small propeller, and the results were well over their rated capacity of 10,000 gallons per minute.

Diameter of steam cylinders, inches	11
Stroke, inches	8
Diameter of pump runner, inches	42
Width of runner, inches	$8\frac{1}{4}$
Diameter of inlet and of outlet nozzle, inches	$15\frac{1}{2}$

Auxiliary Condensers.—There is in each engine room an auxiliary condenser connected with the auxiliary exhaust pipes. The heads and shell are of composition and the tube sheets of

rolled brass. Each has a Worthington horizontal, duplex, combined air and circulating pump, the steam cylinders being between the water cylinders, and all the pistons being on one rod. The tubes are arranged and packed as in the main condensers.

Cooling surface, one condenser, square feet	801
Diameter of steam cylinders, inches	7½
circulating-pump cylinders, inches	8½
air-pump cylinders, inches	8½
Stroke, common, inches	10

Feed-Water Heaters.—In each engine room there is a feed-water heater which is similar in construction to a condenser. The auxiliary exhaust pipe has a by-pass valve, so that the exhaust steam from auxiliaries forward of the engine room may be passed around the tubes of the heater and thence to the condenser. The heaters are located between the feed pumps and the feed main, and the valves are so arranged that the feed water can pass directly to the feed main without passing through the heaters. The heating surface is 496.5 square feet for each heater. The Muntz metal tubes are 1 inch in outside diameter, No. 13 B.W.G. in thickness, and are expanded into the tube sheet. The tubes are tinned inside and out.

Screw Propellers.—The propellers are rights and lefts, of manganese-bronze, each with three adjustable blades bent back 30 inches. They are true screws, with the pitch adjustable from 16 to 18 feet. Each boss is secured to the shaft by two feather keys, and a wrought-steel nut screwed on and locked in place. The end of the hub is covered with a composition cap. The blades and boss are tinned, and the outboard sections of propeller shafts are protected by a covering of insulated copper wire, wound tightly around the shaft casings.

Number of blades	3
Diameter, feet and inches	16– 9
of hub, feet and inches	4– 4½
Length of hub, feet and inches	3– 1
Pitch as set, feet and inches	17– 3
Greatest width of blade, feet	5
Helicoidal area of each screw, square feet	84.2
Projected area, square feet	69.2
Disc area, square feet	220.35
Pitch ÷ diameter	1.03

Boilers.—There are eight single-ended boilers of the horizontal, return, fire-tube type, all of steel. The shells are of one course of four plates, the top heads being curved to a radius of 3 feet 4 inches. The longitudinal joints of the shells are treble riveted with double-butt straps. The joints in furnaces and combustion chambers are single riveted. There are two combustion chambers in each boiler. The tops of the combustion chambers are braced by girders. The combustion chambers are stayed to each other and to the shell by screw stays screwed into both plates and fitted with nuts, the nuts being set up on beveled washers where stays do not come square with the plates. Each furnace is in one piece and corrugated, riveted to flanges of front head and flanged and riveted to combustion-chamber plates. The grate bars are of cast iron, and those at the sides are made to fit the corrugations. The bridge walls are of cast iron, and extend to the back of the combustion chambers. Each boiler has circulating plates fitted at each side of each nest of tubes. Each boiler is bolted to angle irons which are riveted to the saddles. The boilers are bolted rigidly to the angle iron of outboard saddles, but the inboard angle irons have oval holes to allow for expansion. Each boiler has two $4\frac{1}{2}$-inch spring safety valves placed on the stop-valve nozzle, the two valves being in one case. The internal feed pipes are fitted with suction branches to the bottom of the boilers, the combined feed and circulating water being discharged near the water level through down-pointing branches. The auxiliary feed pumps may be used to circulate the water. The tubes in the boilers are of charcoal iron. The boilers are placed athwartships in four watertight compartments. There are two smoke pipes, one for the starboard boilers and one for the port boilers, the pipes being abreast of each other.

BOILER DATA.

Steam pressure, designed, pounds	180
Number of boilers	8
Length, feet and inches	9–11½
Diameter, outside, feet and inches	15– 8
Thickness of shell, inches	$1\frac{7}{16}$
heads, top, inch	$1\frac{7}{16}$

Thickness of heads, bottom, inch	$\frac{3}{4}$
tube sheets, inches	$\frac{7}{8}$ F. $\frac{3}{4}$ B.
furnace, inch	$\frac{9}{16}$
Combustion chambers, number in each boiler	2
thickness of plates, inch	$\frac{9}{16}$
Furnaces, greatest external diameter, feet and inches	3- 7
least internal diameter, feet and inches	3- 3
length of grate, feet and inches	6- 7
number in each boiler (corrugated)	4
Tubes, outside diameter, inches	$2\frac{1}{2}$
length between tube sheets, feet and inches	6- $6\frac{3}{8}$
number of ordinary, each boiler	382
number of stay, each boiler	150
spaced vertically, inches	$3\frac{1}{2}$
horizontally, inches	$3\frac{3}{4}$
thickness of ordinary, No. 9, B.W.G., inch	.148
stay, No. 6, B.W.G., inch	.203
Diameter of rivets in shell sheets, inches	$1\frac{5}{16}$
screw stays, inches	$1\frac{1}{2}$
Number and diameter of upper through braces, inches	10 of $2\frac{3}{4}$
Number and diameter of braces around lower manholes, inches...3 of $1\frac{3}{4}$; from head to back tube sheets, inches, 6 of 2;	6 of $1\frac{7}{8}$ 2 of $2\frac{1}{8}$
Heating surface, tube, each boiler, square feet	2,273.7
furnace, each boiler, square feet	176.4
combustion chambers, each boiler, square feet	256
total, each boiler, square feet	2,706.1
Grate surface, each boiler, square feet	85.6
Area through tubes, each boiler, square feet	13.71
over bridge walls, each boiler, square feet	12.25
Smoke pipes (2), diameter (elliptical), feet and inches.....5-9;	10- 0
area of both, square feet	110.4
height above lowest grates, feet	86.2
Number and diameter of safety valves (2 on one base), inches	$4\frac{1}{2}$
Diameter of boiler main stop valves, inches	7
auxiliary stop valves, inches	6
Volume of furnaces and combustion chambers above grates, cubic feet	349
Steam room, water 4 inches above highest heating surface, cubic feet	355
Water surface, water 4 inches above highest heating surface, square feet,	116
Ratios:	
Tube H.S. to G.S.	26.63
Plate H.S. to G.S.	4.92
Total H.S. to G.S.	31.61
Area through tubes to G.S.	.160
Volume of furnaces and combustion chambers above grates to G.S.	4.07
Steam room per square foot of G.S.	4.14

Total of eight boilers:	
Heating surface, tube, square feet	18,189.6
furnace, square feet	1,411.2
combustion chambers, square feet	2,048.
total, square feet	21,648.8
Grate surface, square feet	684.8
Area through tubes, square feet	109.66

Forced Draft.—The closed fire room system of forced draft is used. The air is supplied by eight Sturtevant blowers, two in each fire room. The fans are driven by two-cylinder vertical, simple, enclosed engines with cranks at 180 degrees.

Diameter of cylinders, inches	5
Stroke, inches	4
Diameter of fan, inches	60
Width of fan at rim, inches	14
Area of induction nozzle, square inches	1,060.7
eduction nozzle, square inches	2,220

Feed Pumps.—There are two main and four auxiliary pumps of the Admiralty type, Worthington duplex, and all of the same size, 10 inches by 7 inches by 12 inches, each capable of delivering 400 gallons per minute. The main feed pumps are located one in each engine room, and draw from the feed tanks and air-pump suctions, and deliver to the boilers. The auxiliary feed pumps are situated in the fire rooms, and draw from the feed tanks, air-pump suctions, sea, drainage system and boilers, and discharge into the boilers, fire main and overboard. The discharges of the main and auxiliary pumps are independent; the main feed pumps discharging only to the boilers.

Fire and Bilge Pumps.—In each engine room there is a vertical, duplex, Worthington pump which draws from the sea, the bilge and drainage system and delivers into the fire main and overboard. They have a capacity of 400 gallons per minute. The steam cylinders are 10 and the water cylinders 7 inches in diameter; stroke, 12 inches.

Water Service Pumps.—In each engine room there is a vertical, duplex, Worthington pump which draws from the sea and delivers into the water-service pipes, the distiller circulating

pipes, the flushing and the fire main. They have a capacity of 400 gallons per minute. The steam cylinders are 10 and the water cylinders 7 inches in diameter; stroke, 12 inches.

Bilge and Sanitary Pumps.—There are two single-acting plunger pumps on each main-engine shaft driven by eccentrics; one pump on each shaft is arranged to draw from the engine room bilges and discharge overboard, the other to draw from the sea and discharge into the flushing main and distiller circulating pipe.

Feed Tanks.—There is a feed tank of 2,000 gallons capacity in each engine room. A part of the tank is fitted as a filter into which the water from the air pumps is delivered; the water descends through the filtering material and discharges into the main portion of the tank. Each tank has a manhole with bolted cover, glass water gage, shut-off cocks and drain cocks. Each tank and filter has the following pipe connections:

A discharge pipe from the air pump;

An overflow pipe to the bilge, so arranged that any water passing down it may be seen;

A suction pipe to feed pumps, with valve;

Drain pipes from traps;

A pipe and valve for drawing water from filter box;

A vapor pipe.

Each feed-pump suction is provided with a balanced valve operated by a copper float in the feed tank, so arranged that it will not allow air to enter the feed pipes.

Steam Traps.—The separators, jackets, main and auxiliary steam pipes, the radiators, and all places where condensed steam can accumulate are fitted with drain pipes and cocks, or valves, and with automatic traps which discharge into the feed tanks. The traps are provided with by-pass pipes and valves, for convenience in overhauling.

Grease Extractors.—A grease extractor is fitted on the discharge of both main feed pumps. It is similar to a Macomb strainer; the basket is perforated and covered with a burlap through which the water filters. By-pass pipes and valves are fitted to feed the boilers while overhauling the extractor.

Engineers' Workshop.—The workshop is fitted on the splinter deck, forward of the engine rooms. The shafting is driven by a single, vertical engine 8 inches by 8 inches. It is provided with the following tools:

One 24-inch screw-cutting lathe; one 14-inch screw-cutting lathe; one column-shaping machine; one double-geared drilling machine; one small drilling machine; one combined hand punch and shears; one emery grinder.

Ash Hoists.—In each fire-room hatch there is a Williamson double, reversible ash hoist, by means of which (with a steam pressure of 60 pounds) one bucket of ashes of 300 pounds can be hoisted in 5 seconds. The steam cylinders are $4\frac{1}{2}$ inches in diameter with a stroke of $4\frac{1}{2}$ inches.

Distilling Apparatus.—In the engine rooms are two Williamson Bros. straight-tube distillers, and two evaporators, Bureau's pattern, with a combined capacity of potable water at a temperature of 90 degrees Fahrenheit of 7,500 gallons in twenty-four hours. The water-service pumps are used for the distiller circulating water. The distillers are arranged so that that they can take steam from the auxiliary steam pipe in case of emergency. A filter and water meter are fitted to each distiller. There are two evaporator feed pumps of the Worthington horizontal duplex type, and two combined brine and fresh-water pumps of the same type.

Ice Machine.—There is one 2-ton Allen dense-air ice machine capable of producing the cooling effect of two tons of ice per day. The cooling pipes connect to the ice tanks, refrigerating rooms, scuttle butt and eight magazines. Steam cylinder, $9\frac{1}{4}$ inches diameter; air-compressor cylinder, 7 inches diameter; air-expansion cylinder, $5\frac{3}{4}$ inches diameter; stroke, 13 inches.

Ventilating Fans.—In each engine-room hatch there is a ventilating fan for engine-room ventilation only. For ventilating the ship generally there are six fans situated two on the berth deck and four on the splinter deck. These are arranged to force air to the various parts of the ship only. In the steering-engine room there is an electrical exhauster driven by a $2\frac{1}{2}$-H.P. electric motor. The fans were furnished by the Sturtevant Company.

Diameter of steam cylinders, compound, inches	4 and 7
Stroke, inches	4
Diameter of fan, inches	50
Width of fan, inches	17½

Steering Engine.—On the after platform deck there is a Williamson Bros. combined hand and steam steering engine; cylinder, 14 inches in diameter; stroke 11 inches. The engine is controlled from the conning tower and pilot house by means of hydraulic telemetor or by wire rope.

Torpedo Compressors.—There are two Bliss, type V, air compressors for torpedoes, of a direct acting vertical pattern, with one direct acting steam cylinder in the base, and one single-acting high-pressure and two double-acting low-pressure cylinders in the water compartment.

A sliding crosshead on the steam piston rod actuates the crank shaft, to which are attached valve gear and fly wheel.

Steam cylinder, diameter, inches	12
L.P. air cylinders (2), diameter, inches	7
H.P. air cylinder (1), diameter, inches	2¾
Stroke, common, inches	6

Compression.—1st stage: top of L.P. cylinder to 15 pounds;
2d stage: bottom of L.P. cylinder to 235 pounds;
3d stage: top of H.P. cylinder to 1,500 pounds.

Steam Windlass.—There is a steam windlass, built by the Hyde Ship Windlass Company, situated forward on the main deck. The engine is a reversible, double-cylinder, vertical, direct-acting, with cylinders 15 inches in diameter and a stroke of 14 inches. The windlass is fitted with two wildcats to take the chains.

Steam Winches.—There are four steam winches situated as follows:

On the upper deck forward of the forward turret, one double-cylinder, horizontal, two-speed steam winch, 8 inches by 8 inches, link reversing engines, built by the American Ship Windlass Company, of Providence R. I.

On the upper deck in the superstructure, two double-cylinder,

horizontal, single-geared ship winches, 8¼ inches by 8 inches, built by the Lidgerwood Mfg. Company.

On the main deck, abaft the after turret, one double-cylinder, compound, geared ship winch, 8¼ inches by 8 inches, built by the Lidgerwood Mfg. Company.

Boat Crane Engines.—There are two boat-crane engines situated on the upper deck for hoisting in and out boats. They were built by the contractors. Steam cylinders, 11 inches in diameter, stroke, 8 inches.

Telegraphs and Revolution Indicators.—There is a Cory mechanical telegraph in each engine room connected to transmitters in conning tower, pilot house and bridge, and a mechanical gong in each engine room with bell pulls on deck. Mechanical tell-tales are fitted on the bridge, in the conning tower and chart house to show the direction of the revolution of the main engines. In each engine room there is a mechanical indicator to show the relative speed and direction of revolution of the main engines. The two indicators are connected, and each has two hands, a red one which turns with the port engine and a green one which turns with the starboard engine. The hands can be turned on their shafts like the hands of a watch, so that by setting them together the relative speed of the propellers can be seen as the hands separate or remain together in their revolutions over the dial of the indicator.

Telephones and Voice Tubes.—For communication between the various parts of the ship there is a complete system of telephones and voice pipes with call bells. The important stations are connected directly, but for general purposes, in order to lessen the number of pipes, a central station is used.

Steam Cutters.—There are two steam cutters, one 36 feet and one 33 feet long. They have Ward boilers, compound engines and keel condensers. The engines of both cutters are the same size; cylinders 4 inches and 8 inches in diameter by 6 inches stroke.

Electric Plant.—The installation consists in general of eight generating sets, 800 incandescent lights, 4 searchlights, two sets of signalling apparatus, one main switch board, one searchlight

switch board, together with the necessary wire, wiring accessories, molding and fixtures, and the motors given in the table. The eight generating sets were made by the General Electric Company. In each set there is a 32-kilowatt dynamo of multipolar type, having a capacity of 500 ampères at 80 volts, compound-wound six-pole. The engines driving the dynamos are compound, tandem, vertical, inverted; diameter of cylinders, 9 and 15 inches, stroke, 6 inches. The engines are designed to run with full load at 400 revolutions per minute with 100 pounds steam pressure. The bed plate is common to both engine and dynamo. The incandescent lights are of 16 and 32 candlepower, designed for 80 volts.

Each of the dynamos is connected to the main switch board. The main switch board contains the panels for the dynamos, and the lighting, power, turrets and searchlights bus bars, and the switches of lighting circuits and motor feeders. The searchlight board receives current from the main boards.

The ship is wired on the 2-wire system.

There are four searchlights, made by the General Electric Company, two mounted on a platform on the mainmast and two on the pilot house abreast the foremast. The projectors are 30 inches in diameter, and hand controlled. All lamps are of the horizontal type with combination hand or automatic feed, and designed for a current of 75 to 90 ampères at about 50 volts. The carbon holders are adjustable, and the life of the carbon is six hours.

The signal apparatus is in two sets, one for each mast, of the usual Ardois type, and consists of four double signal lanterns to each set, with cable connections and keyboard on the forward and after bridges.

Electric speed indicators and transmitters are fitted in the pilot house and in the conning tower; also, electric helm indicators and electric steering-engine telegraphs.

There are mercurial thermostats in each coal bunker and in certain storerooms, with an annunciator on bulkhead forward of cabin, and a mechanical thermostat in each magazine with annunciator at after bulkhead of ward room.

ELECTRIC MOTORS.

Name.	No.	H.P.	Revs.	Volts.	Amps.
Turret turning	4	50	400	80	600
13-inch ammunition hoists	4	20	350	80	225
13-inch elevating	4	3.5	300	80	45
13-inch rammer	4	5	775	80	60
6-inch and 6-pounder chain ammunition hoists	18	3.75	375	80	45
6-pounder winch ammunition hoists	6	6	375	80	75
Ventilating fans (supply)	2	8	500	80	95
Ventilating fans (exhaust)	1	2	1,030	80	26
Ventilating fans (exhaust)	2	1½	1,220	80	14
Ventilating fans (exhaust)	2	¾	1,650	80	8
Smoke blowers	2	½	1,850	80	6
Portable pumps	2	1⅛	1,200	80	14

CONTRACTORS' FORCE ON TRIP AND ON TRIAL.

In the following table are given the number of men employed by the contractors to run the machinery on the trip to Boston and during the trial, with the stations of the men:

WATCHES UNDER NATURAL DRAFT.

	8 to 12.	12 to 4.	4 to 8.	No. each rate.
Engine force:				
Engineers	2	2	2	6
Machinists	2	2	2	6
Oilers	9	9	9	30
Oiler, ice machine	1	1	1	
Pumpers	1	1	1	3
Apprentices	3	3	3	9
Storekeepers	1	1	1	3
	— 19	— 19	— 19	— 57
Fire-room force:				
Water tenders	2	2	2	6
Firemen	9	8	8	25
Coal passers	8	8	8	24
F. R. machinists	1	2	2	5
Auxiliary men	8	7	7	22
	— 28	— 27	— 27	— 82
Grand total	...	...	...	— 139

Those who operated dynamos are left out of this list.

The coal was at the doors and was shoveled into fire rooms without any attempt at tallying.

FOUR HOURS' FORCED-DRAFT TRIAL.

Engine force:

Engineers	3
Machinists	7
Oilers	18
Apprentices—Oiled auxiliaries in engine rooms	6

Engine force:			
Pumpers		2	
Storekeepers		2	
Auxiliaries Spare men	Acted as oilers—all were used	4 6	
			48
Fire-room force:			
Boilermakers		4	
Machinists		8	
Water tenders		4	
Firemen		16	
Coal passers		16	
Engineers		2	50
Firemen who replaced men worn out during run			12
			110

The coal was in bags at the bunker doors, and was thrown into fire rooms without attempt at tallying. No auxiliaries running outside engineer department, except blowers in engine hatch. No men stationed at stop-valve closing gear, watertight doors, bunker smothering pipes, air and exhaust pipes to bunkers.

SHIP'S COMPLEMENT.—ANALYSIS OF STATION BILLS.

FORCED-DRAFT BATTLE CONDITION.

Sta. No.	Rate.	Duty.	S. E. R.	P. E. R.		
1	C. M....	Running main engine	1	1		
2	C. M....	Middle platform	1	1		
3	C. M....	Air and circulating pumps, feed heaters, valve manifolds	1	1		
4	M. 2 C...	Fire and bilge pumps	1	1		
5	Oilers...	Middle platform (should be one for each cylinder)	2	2		
6	Oilers...	Lower platform (should be one for each M. E. S. A. auxiliaries)	2	2		
7	B. S.....	Tending engine room doors	1			
8	Oilers...	Top platform	0	0		
			Fire rooms.			
			1	2	3	4
9	B. M....	Aux. feed pump, W. T. doors, manifolds	..	..	1	1
10	W. T....	Tending water	1	1	1	1
11	W. T....	Aux. feed pump, W. T. doors, manifolds	1	1	..	..
12	Oiler....	Forced-draft blowers	1	1	1	1
13	F. 1 C...	Fire-room escape and hatch doors	1	1	1	1
14	F. 1 C...	Fires	4	1	4	1
15	F. 1 C...	Int. bunker doors—in charge getting coal	1	1	1	1
16	F. 2 C...	Fires	1	2	1	2
17	F. 2 C...	Getting coal	2	4	2	4
18	C. P.....	Getting coal	4	4	3	2

Auxiliary stations outside engine and boiler compartments.

Sta. No.	Rate.	No.	Stations.
19	M. 1 C..	1	Starboard ammunition passage—bunker, escape, smothering pipes, air exhaust and supply valves.
20	M. 1 C..	1	Port ammunition passage—ditto.
21	M. 1 C..	1	Berth deck—stop-valve closing gear; safety-valve lifting gear. (Two men needed for this.)
22	M. 2 C..	1	After splinter-deck blowers—fire main valves.
23	M. 2 C..	1	Forward splinter deck blowers—ditto.
24	C. S.....	1	Berth deck blowers—main-drain cistern valves.
25	M. 1 C..	1	Ice machine—As this machine cools magazines, it will have to be kept in readiness.
26	C. P.....	6	Cooks.
27	C. P.....	2	Storekeepers.
28	C. P.....	1	Messenger.
29	C. P.....	31	Ammunition division.

NOTES.

No spare man in engine force, and stations Nos. 5 and 6 inadequately covered.

Station No. 7 not covered at all. Must be taken care of by Nos. 5 and 6.

Stations Nos. 4, 8 and 10, cover the whole drainage system of the double bottoms and all the hold compartments, also fire service. Two more men are needed, due to position of pumps and manifolds.

No. 21 is too large to be covered by one man, and it is of first consequence.

NUMBER IN ORDINARY STEAMING, THREE WATCHES.

No. of Station.	Rate.	Engine.		Duty.
		Starboard.	Port.	
1	C. M.....	1	1	Running main engines.
2	M. 1 C. or M. 2 C...	1		Ice machine.
3	Oilers.....	2	2	Main engine room.
4	M. 2 C. or C. S.....	1		Aux'y outside engr. dept.

FIRE-ROOM FORCE.

No. of Station.	Rate.	No. 1.	No. 2.	No. 3.	No. 4.	Duty.
5	W. T.....	1		1		Tending water.
6	F. 1 C.....	2	2	1	1	Fires.
7	F. 2 C.....	1	1	2	2	Fires.
8	C. P.....	4	3	4	2	Coal.

FOR REPAIR WORK—EVAPORATORS.

No.	Rate.	Duty.
1	M. 1 C.....	For general repair work, launches, etc.
2	B. M.....	General repair work.
3	B. S.....	General repair work.

To be used on evaporators when they can be spared.

OFFICIAL TRIAL.

The official speed trial took place off the New England coast, between Cape Ann and Cape Porpoise, on the 12th of June, 1901, and consisted of two runs over a measured course 33 nautical miles in length. The average speed for the two runs, after correction for tidal observations, was 17.449 knots. As will be noticed from the halftone illustration of the ship while on the course, the weather conditions were favorable. There was an abundance of steam, and the passover valves on the first and second receivers were partly open during the greater part of the trial. The coal was New River, of excellent quality.

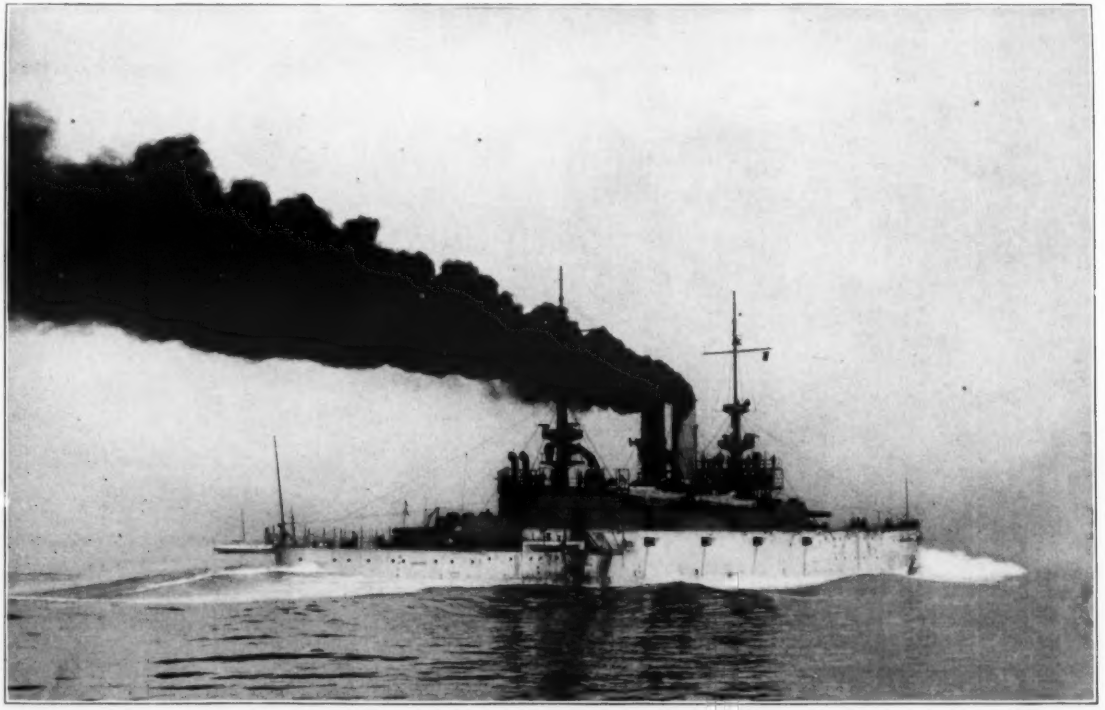
FERFORMANCE—SYNOPSIS OF STEAM LOG.

Main Engines.

Steam pressure at boilers, per gage, pounds	177	
	Starboard.	*Port.*
H.P. steam chest, per gage, pounds	175.8	174.1
first receiver, absolute, pounds	86.2	87.6
second receiver, absolute, pounds	32.2	32.2
Vacuum in condensers, inches of mercury	24.6	24.3
Mean effective pressures in cylinders of main engines, pounds per square inch, H.P.	68.45	65.38
I.P.	37.94	41.17
L.P.	17.08	18.2
Mean pressure on L.P. piston, equivalent to aggregate M.E.P. on all pistons, pounds per square inch	45.57	47.5
Mean effective pressure, air pump cylinders	14.06	14.56
circulating pump cylinders	13.92	14.61
Revolutions per minute:		
Main engines	118.4	117.3
Pumps, air	30	36.5
circulating	147	161
feed, double strokes per minute	33.9	
Blower engines, mean revolutions	360.2	
Speed of ship in knots per hour	17.449	
Slip of propeller in per cent. of its own speed, based on mean pitch	13.54	12.7
Air pressure in fire rooms, in inches of water	0.7	

Indicated Horsepower.

Main engines, H.P.	1,689.52	1,598.91
I.P.	2,199.3	2,366.7
L.P.	2,330.6	2,461.6



U. S. S. 'ILLINOIS."

Photograph copyrighted by N. L. Stebbins, Boston, Mass.

	Starboard.	*Port.*
Air pump	8.16	10.48
Circulating pump	15.36	17.66
Feed pumps	58.71	
Water-service pumps and all auxiliary machinery in use	5.73	
Ventilating engines for engine rooms	10	
Blower engines for forced draft in fire rooms	69.6	
Dynamo engines	56.35	
Collective of all main engines	12,646.6	
main engines, air, circulating and feed pumps	12,757 (*A*)	
and auxiliary engines in operation during trial	12,898.7 (*B*)	
Main engines, air, circulating and feed pumps, per sq. ft. G.S.	18.63	
H.S.	.589	
Cooling surface, square feet, per I.H.P., (*B*)	1.102	
Heating surface, square feet, per I.H.P., (*B*)	1.678	

COAL.

Kind and quality ..... New River, excellent.

EXAMINATION OF MACHINERY AND BOILERS AFTER TRIAL.

Machinery.—Port after main bearing heated during trial, and the white metal started to run. Returning to Newport News from Boston, Mass., after the trial, the bearing ran perfectly cool. Heating not due to defective workmanship, but to dirt stopping up oil pipe. The bearing was not marked. Other than this there was no evidence of stress in any of the machinery.

Boilers.—One tube leaked slightly. The furnaces were trammed before and after trial, and the measurements were practically identical, the differences being due to the fact that different men took the two measurements.

The cylinders, valves, condensers and boilers were carefully examined and found almost totally free from oil or grease.

A number of joints and expansion joints in pipes leaked, but this was to be expected as the machinery has been in the ship nearly 18 months.

CONTRACT TRIALS OF THE TORPEDO BOATS *SHUBRICK* AND *THORNTON.*

By Commander H. Webster, U. S. Navy.

The *Shubrick* and *Thornton* are twin-screw torpedo boats of 165 tons displacement, and were built by the William R. Trigg Company, of Richmond, Va., on the general plan and specifications furnished by the Navy Department. The contracts for these two boats, together with that for the *Stockton*, were signed on November 16, 1898, the price being $129,750 each, and the time allowed for completion one year. The price stated above does not include ordnance and ordnance outfit and a few other articles supplied by the Government.

The time for completion was afterward extended to May 1, 1901, for various reasons, the principal of which was the difficulty experienced in procuring material.

The speed guaranteed was 26 knots per hour, to be maintained successfully for two consecutive hours, during which period the average air pressure in the fire rooms was not to exceed $4\frac{1}{2}$ inches of water, the vessel to be weighted to a displacement of 165 tons. There was no premium provided for excess of speed over that required by the contract, but it was stipulated that a penalty, at the rate of $12,000 per knot, was to be inflicted in case the speed fell to 25 knots, and that the Secretary of the Navy should reject her in the event of the speed being less than 25 knots. The weight of the machinery was limited to 80 tons, not to include stores and spare parts supplied by the Government, steam steering gear, steam windlass, dynamo engine and torpedo air-compressing machinery.

The penalty for overweight of machinery was $200 per ton over 80 tons, and if this overweight exceeded 5 per cent. of the contract weight then $1,000 additional was to be deducted from the contract price of the vessel.

U. S. S. "SHUBRICK."

HULL.

The hull is constructed of mild steel of domestic manufacture, with frames spaced 18 inches apart, except in the engine compartments where they are spaced to suit the engine-bed plate variations.

The thickness of the keel plate is 10 pounds per square foot for a length of 100 feet amidships; forward and abaft of this it is $7\frac{1}{2}$ pounds. The vertical keel is 15 pounds per square foot and 8 inches deep. The outer plating is 7 pounds per square foot; at the ends it is reduced to 5 pounds forward and 6 pounds at the stern.

The vessel is divided into ten watertight compartments: first compartment, the trimming tank; second compartment, windlass and engines; third compartment, officers' quarters—below the floor of quarters, stores and ammunition; fourth compartment, two boilers; fifth compartment, starboard engine room; sixth compartment, port engine room; seventh compartment, one boiler; eighth compartment, galley and crew space; ninth compartment, crew space; tenth compartment, trimming tank.

COAL BUNKERS.

There are eight coal bunkers, with a total capacity of 80 tons at 43 cubic feet to the ton. There are two hydraulic ash ejectors, one fitted in each fire room.

HULL DATA.

Length between perpendiculars, feet	175
on L.W.L., feet	175
over all, feet	175
Beam extreme, feet and inches	17– 6
at L.W.L., feet and inches	16– 8
Ratio of length to beam	10.17 to 1
Beams to top of floor, feet and inches	11-10
Mean draught, seagoing trim, feet and inches	5– 4½
Displacement, seagoing trim, tons	215
per inch at L.W.L., tons	5.65
Area of immersed midship section, square feet	71
Center of gravity of L.W.L. plane aft of midship section, feet	10.9
Center of buoyancy above bottom of keel, feet	3.5
aft of midship section, feet	2.9
Transverse metacenter above center of buoyancy, feet	6
Longitudinal metacenter above center of buoyancy, feet	550
Number of frames	115

The battery consists of three 3-pounder semi-automatic rapid-fire Maxim guns, and three Whitehead torpedo tubes, the air compressor for which is of the Bliss type 1–A.

MAIN ENGINES.

There are two vertical, inverted, direct-acting, triple-expansion, four-cylinder engines, placed in separate watertight compartments, the starboard engine forward, and the port engine aft. In the cylinder arrangement the high-pressure cylinder of each engine is forward and the low-pressure cylinder aft. The cylinders are supported by vertical, forged-steel, cylindrical columns, stayed by forged and cast-steel ties and braces. Live steam may be admitted to both receivers. The main valves are of the single-ported, piston type, there being for each engine, one for the H.P., one for the I.P. and one for each of the L.P. cylinders. The I.P. and L.P. main valves are provided with balance pistons, the cylinders of which form part of the upper covers of the valve chests. The valve gear is of the Stephenson link type, with double-bar links. There are no independent cut-off valves, but provision is made to cut off in each cylinder, varying from $\frac{5}{10}$ to $\frac{7}{10}$ of the stroke, by means of a block to which the suspension links are attached, which block can be moved by a hand screw geared in a slot in the end of the arm on the reversing shaft.

The main pistons are steel forgings, dished, and are fitted with two packing rings, each $\frac{5}{8}$ inch wide and $\frac{7}{16}$ inch thick. The piston rods, connecting rods and crossheads are of forged nickel-steel. The go-ahead sliding face of the crossheads is fitted with white metal. The ahead guide is of cast iron bolted to the engine-frame strongbacks, and is cast hollow for the circulation of water. Composition lips are bolted on each side of the ahead guide to take the thrust when backing. The eccentrics are forged on the shaft. The eccentric straps are of composition faced with white metal, and the eccentric rods of forged nickel-steel. Each engine bedplate consists of separate girders, one under each bearing. The reversing gear consists of a steam cylinder with piston acting directly on an arm fixed on the re-

versing shaft. The valve of this engine is worked by a system of differential levers, the primary motion being derived from the hand lever at the working platform and the secondary motion from a point on the reversing arm. The turning gear consists of a worm wheel on the main shaft worked by a hand ratchet.

Each engine is fitted with a double poppet, balance stop valve, $5\frac{1}{4}$ inches diameter.

ENGINE DATA.

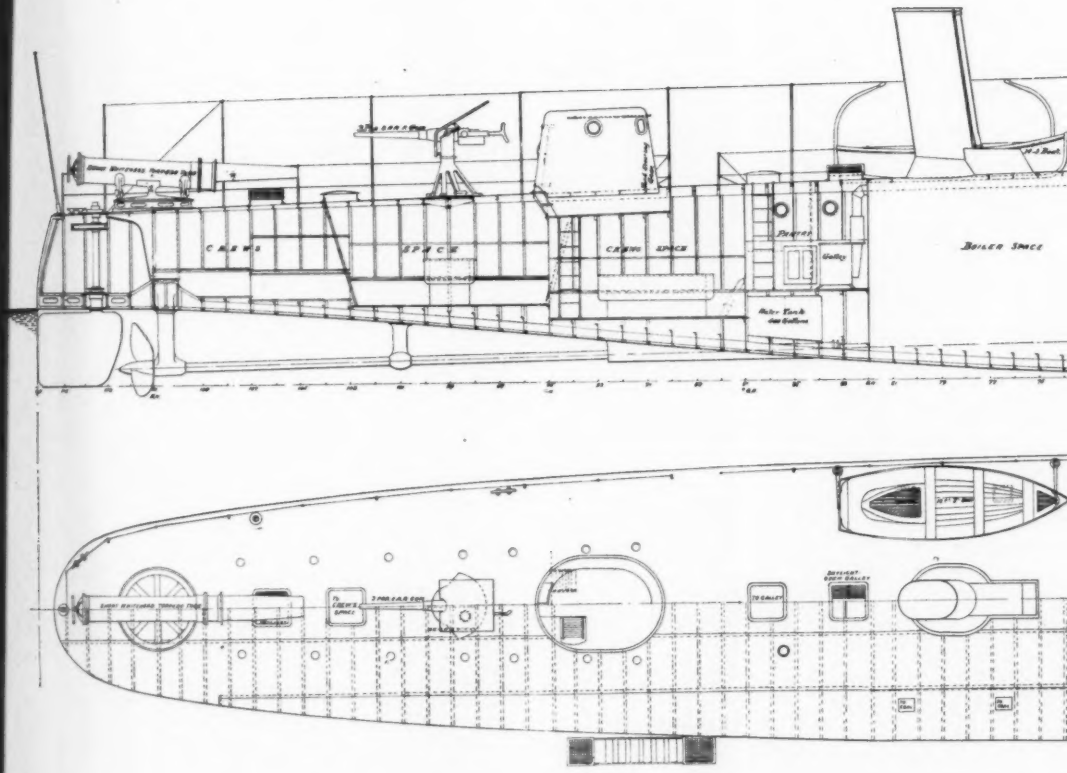
Cylinders, number for each engine	4
H.P., diameter, inches	14
I.P., diameter, inches	22
L.P. (2), diameter, inches	$25\frac{1}{4}$
Stroke	18
Valves, H.P. (1 for each cylinder), diameter, inches	$7\frac{1}{2}$
I.P. (1 for each cylinder), diameter, inches	$14\frac{1}{2}$
L.P. (1 for each cylinder), diameter, inches	$16\frac{1}{2}$
Balance pistons, I.P., diameter, inches	$4\frac{3}{4}$
L.P., diameter, inches	$4\frac{3}{4}$
Valve stem, H.P. (1), diameter	$1\frac{3}{8}$
through valve, inches	1
I.P. and L.P. (1 each), diameter, inches	$1\frac{5}{8}$
through valve, inches	$1\frac{1}{4}$
Main steam pipe, diameter, inches	$5\frac{1}{4}$
exhaust pipe to condenser (2), inches	$9\frac{1}{2}$
Piston rods, diameter, inches	3
length from piston to center of crosshead pin, inches	$31\frac{3}{16}$
axial hole diameter, H.P. and I. P., inches	$1\frac{3}{16}$
L.P., diameter, inches	2
Connecting rods, center to center, inches	40
H.P. and I.P., section at upper end, inches	$1\frac{1}{2}$ by $3\frac{3}{4}$
L.P., section at upper end, inches	$1\frac{1}{2}$ by 3
H.P. and I.P., section at lower end, inches	1 by 5
L.P., section at lower end, inches	$\frac{7}{8}$ by $4\frac{1}{2}$
Crank-pin bolts (2), diameter, inches	$1\frac{7}{8}$
Crosshead pins, diameter, inches	$3\frac{3}{8}$
length of H.P. and I.P., inches	$5\frac{1}{2}$
L.P., inches	$4\frac{1}{2}$
axial hole, diameter, inches	$1\frac{1}{2}$
H.P. and I.P., wearing surface, ahead, width	$7\frac{1}{2}$
length	$13\frac{1}{2}$
backing (2), width	2
length	$13\frac{1}{2}$
L.P. wearing surface, ahead, width	$6\frac{1}{2}$
length	$11\frac{1}{2}$
backing (2), width	$1\frac{3}{4}$
length	$11\frac{1}{2}$

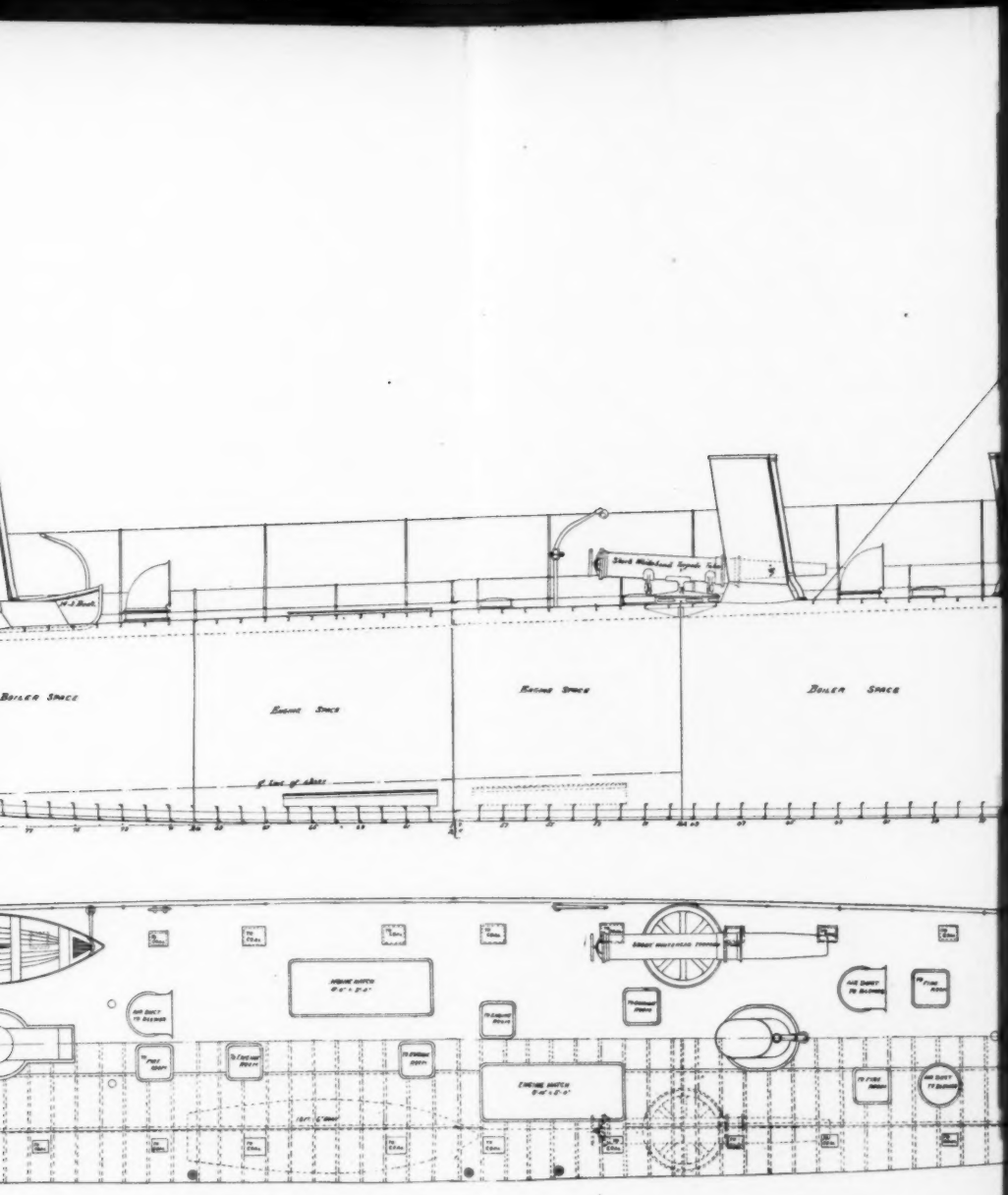
Cylinder diameters.	H.P., 14 ins.	M.P., 22 ins.	1st L.P., 25.25 ins.	2d L.P. 25.25 ins.
Common cylinder ratio	1 : 6.506	1 : 2.605	.....	.....
Net piston areas, square inches, average top and bottom	150.4	376.59	497.2	497.2
Volume of cylinders without clearance, cubic inches:				
Top	2,770.8	6,842.4	9,013.36	9,013.36
Bottom	2,643.6	6,715.17	8,886.11	8,886.11
Average	2,707.27	6,778.78	8,949.74	8,949.74
Volume of clearance, cubic inches:				
Top	707.44	1,718.06	1,718.06	1,718.06
Bottom	620.81	1,559.25	1,518.13	1,578.69
Average	664.13	1,638.65	1,653.09	1,648.38
Volume of cylinders with clearance, cubic inches:				
Top	3,478.32	8,560.47	10,731.42	10,731.42
Bottom	3,264.47	8,274.42	10,474.24	10,459.8
Average	3,371.4	8,417.44	10,602.83	10.595.61
Percentage of clearance:				
Top	25.53	25.10	19.06	19.06
Bottom	23.48	23.20	17.87	17.71
Average	24.50	24.15	18.46	18 38
Volumetric cylinder ratios, average, top and bottom	1 : 6 292	1 : 2.518	.....	.....

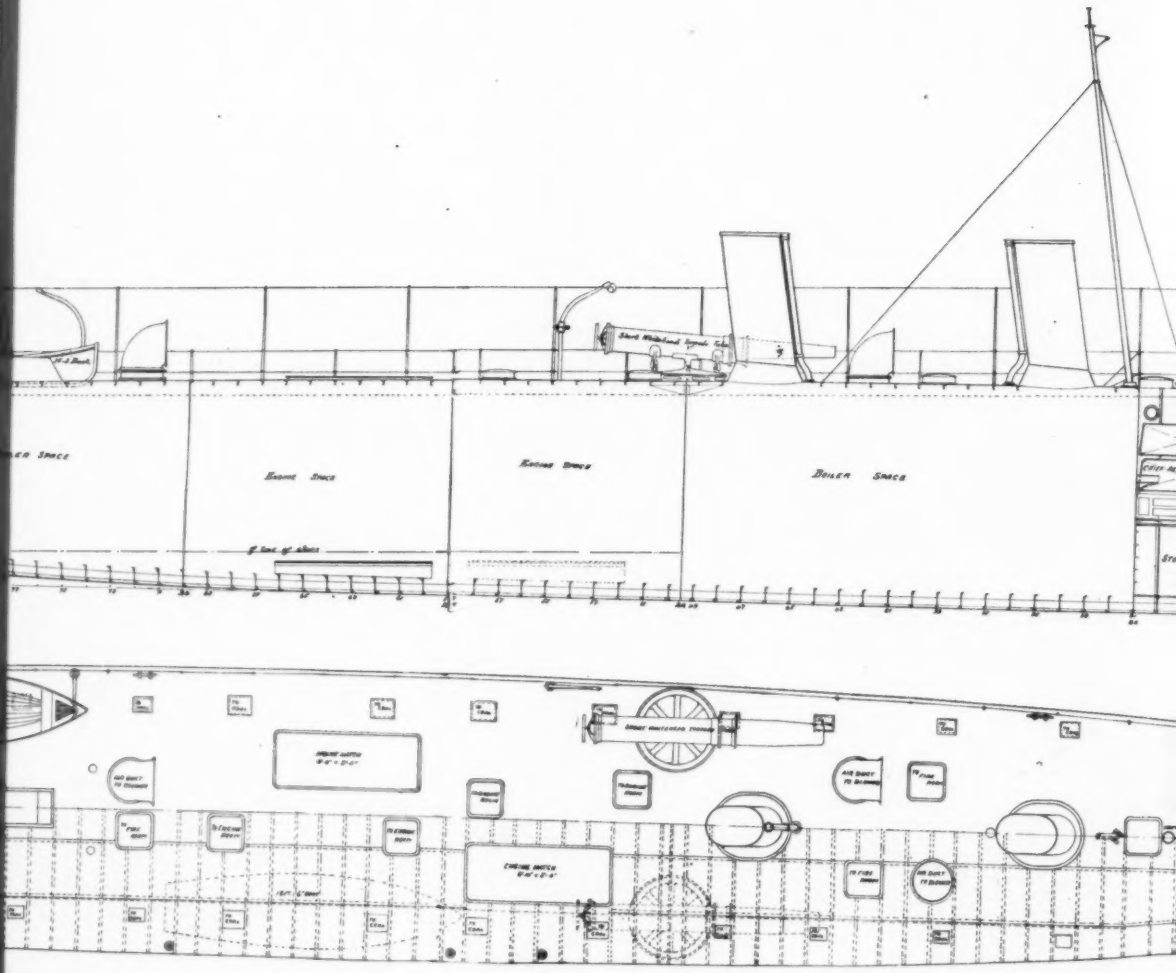
Shafting and Bearings.—The crank, thrust, stern-tube and propeller shafting is hollow and of forged nickel-steel. The crank shaft of each engine is in one piece, with the eccentrics forged on. The cranks of the H.P. and I.P. are opposite, and the two L.P. are similarly placed with regard to each other. The H.P. and I.P. make an angle of 90 degrees with the first and second L.P., and the sequence of cranks is, therefore, H.P., first L.P., I.P. and second L.P. The forward end of the stern-tube shaft is supported by a spring bearing. The propeller shafts are covered with a composition casing from the forward coupling to three-quarters of an inch inside the propeller hub.

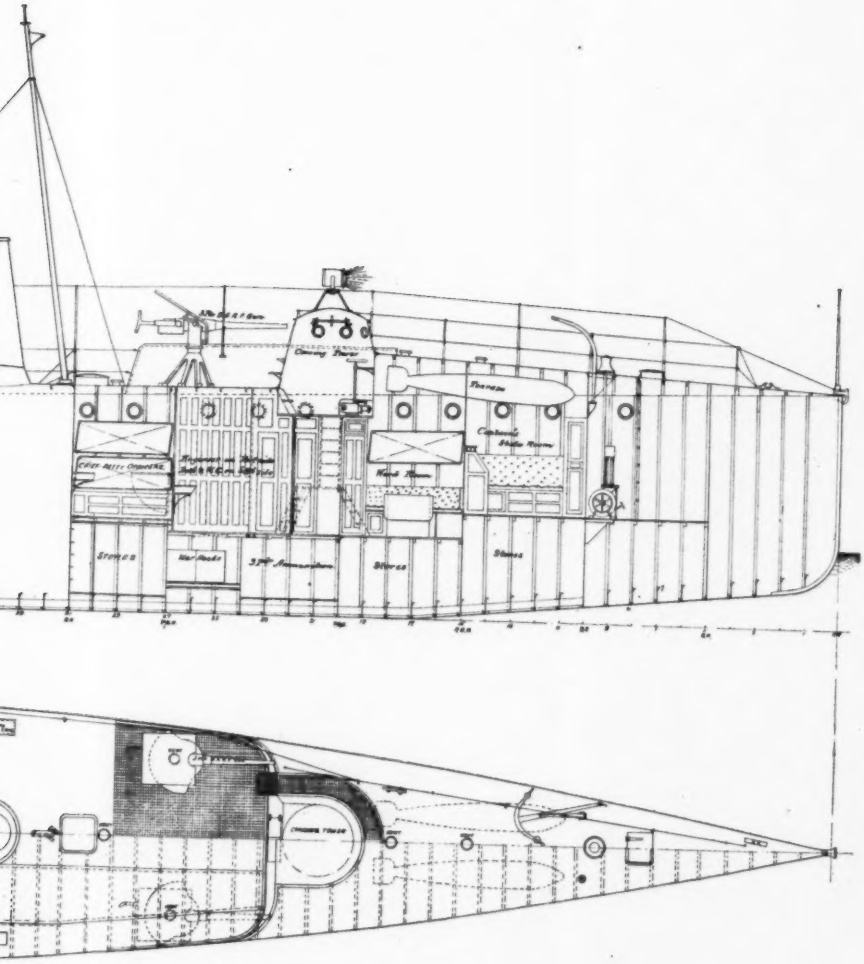
The coupling of the stern-tube and propeller shafts consists of a forged-steel sleeve 25 inches long secured by one key lengthwise and two cross keys.

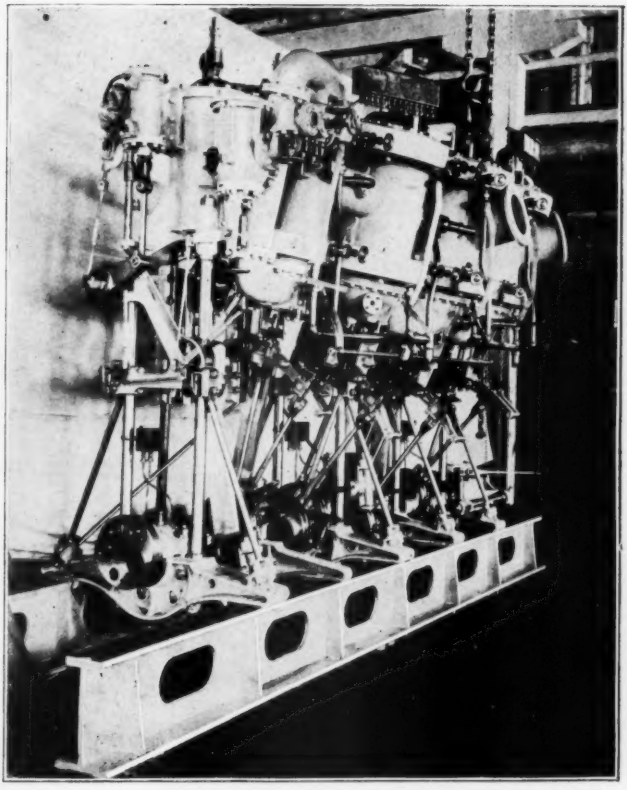
Each thrust bearing is of the collar type, made of cast steel; it is water jacketed, and is secured to the after girder of the engine-bed plate by a 2-inch-diameter steel strut. The bearing faces are white metal. There is an oil cup, common to all collars, the white metal being channeled for the distribution of oil.


CARGO
SPACE
CABIN SPACE
PANTRY
BOILER SPACE
TO CREW'S SPACE
TO GALLEY


BOILER SPACE
ENGINE SPACE
ENGINE SPACE
BOILER SPACE


Engine Space
Boiler Space





ENGINES OF THE "SHUBRICK."

Crank shaft, diameter, inches	6¼
axial hole, diameter, inches	4
coupling disc, diameter, inches	12⅛
thickness, inches	1⅛
tapered coupling bolts (6), inches	1⅜ to 1⅛
journals, diameter, inches	6¾
length (4), inches	8⅜
length (1), inches	4⅜
length port shaft, feet and inches	10– 4¾
starboard shaft, feet and inches	10– 7⅛
Crank pins, diameter, inches	6¾
length, H.P. and I.P., inches	9
L.P., inches	7
Crank webs, width, inches	8
thickness, H.P. and I.P., inches	3
1st L.P., inches	3½
2d L.P., inches	3¾
Thrust shaft, diameter, inches	6
coupling disc, diameter, inches	12⅛
axial hole, diameter, inches	3½
collars, number each shaft	12
diameter, inches	8⅛
thickness, inch	½
space between, inch	1
length, port, feet and inches	10– 1¼
starboard, feet and inches	21–11¼
Stern tube shaft, diameter, inches	6
axial hole, diameter, inches	3½
length, feet	25
Propeller shaft, diameter, inches	6
axial hole, diameter, inches	3
length, feet and inches	33– 3⅜
Stern-bracket bearing, length, inches	18½
diameter, inches	6¾
Stern-tube bearings, length forward, inches	21
aft, inches	21

Condensers.—There are two main condensers, one for each engine. The shells are of Muntz metal plate, No. 10 B.W.G., made of two cylindrical plates butted together, secured and stiffened by Tee butt straps of Muntz metal. The water chests are of copper with tube sheets of Muntz metal. The circulating water passes through the tubes. A baffle plate with slots is fitted the entire length of the condenser to direct the steam over the tubes. The inlet pipe is fitted with a small circulating pump to act as sup-

plementary supply to the water forced through the condenser by the speed of the boat.

Diameter of shell, inside, inches	38½
Thickness of shell	No. 10 B.W.G.
Tubes, diameter, inch	⅝
length between tube sheets, inches	73½
thickness, No. 18 B.W.G., inch	.049
number in each condenser	1,248
Cooling surface each condenser, square feet	1,250.4
Cooling surface, total, square feet	2,500.8
Ratio total cooling to total heating surface	.302

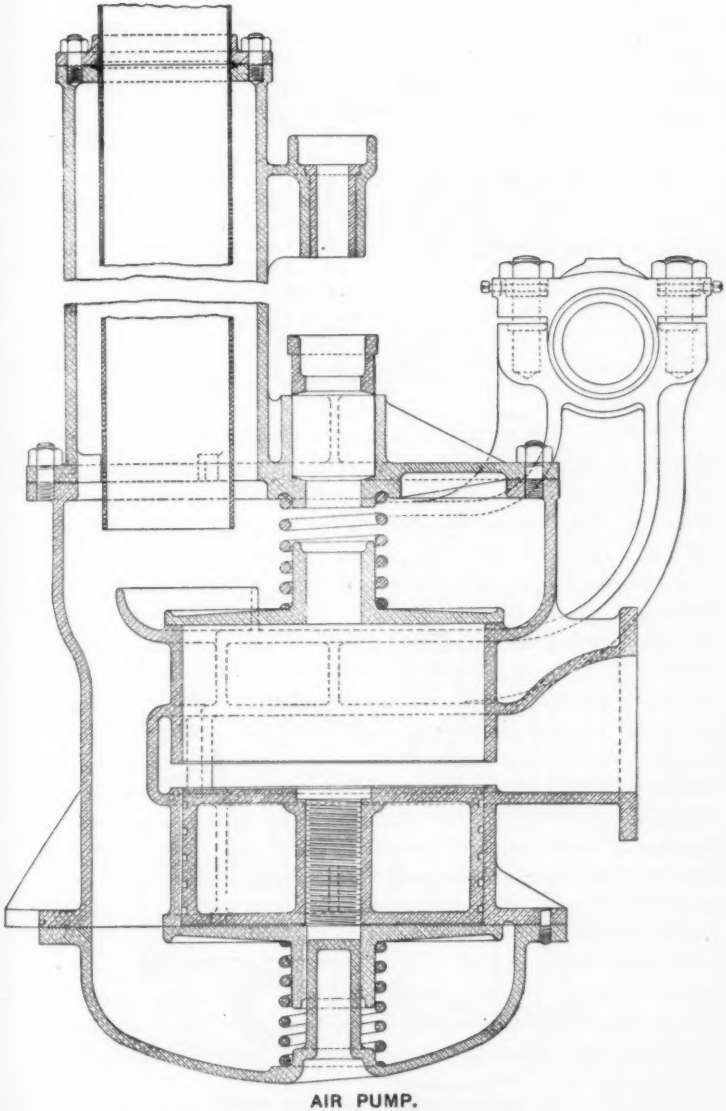
Air Pumps.—For each engine there is a single-cylinder, double-acting, vertical, Bailey air pump, worked from an eccentric on the main shaft directly abaft the engine. The eccentric rod actuates a rock shaft, to which arms are attached, and the latter are connected to the air-pump crosshead by double-bar links. A pump valve covers each end of the barrel, and the suction of the pump is through an annular opening at the center of the barrel.

Diameter of pump, inches	11
Stroke of pump, inches	6
Diameter of pump rod, inches	2
Diameter of rock shaft, inches	3

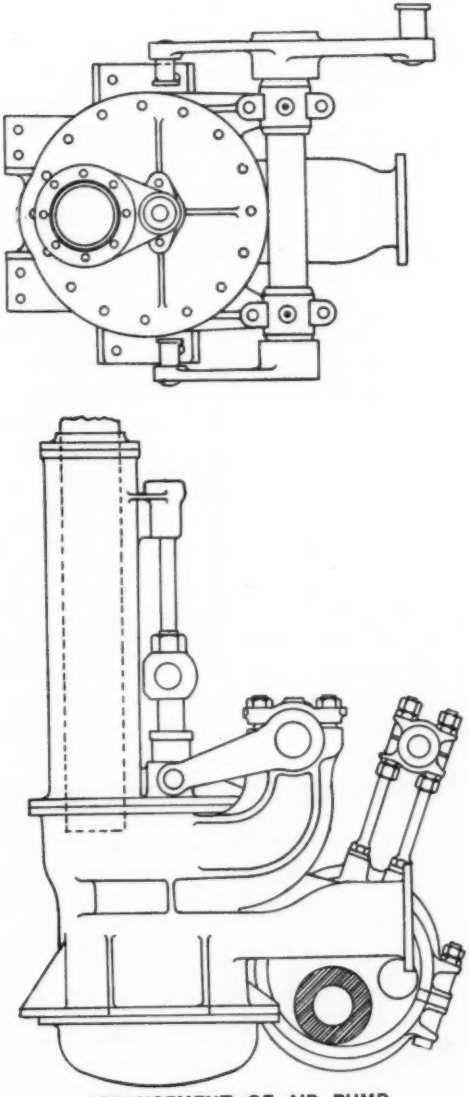
The air pump is illustrated as constructed and as run on the official trials; but in service it has been found necessary to guide the crosshead in order to overcome a tendency of the piston to turn and bring undue strain on the links if the connections are slack.

Circulating Pump.—For each main condenser there is a centrifugal, double-inlet circulating pump, which is arranged to draw water from the sea, the bilge and main drain, and to discharge into the condenser as a supplemental supply. It is driven by an independent, vertical, single-cylinder engine.

Steam cylinder, diameter, inches	4
Stroke, inches	3
Pump runner, diameter, inches	18
Width at periphery, inches	1⅜
Inlet nozzle, diameter, inches	5⅞
Outlet nozzle, diameter, inches	5



AIR PUMP.



ARRANGEMENT OF AIR PUMP.

Screw Propellers.—The propellers are of manganese-bronze, tinned, each with three blades. They are true screws, bent back 9 inches at the periphery, the starboard one left-handed and the port one right-handed. They are of the modified Griffiths type. Each propeller is secured to its shaft by a single key and a composition nut screwed on and locked in place.

Number of blades	3
Diameter, feet and inches	5– 8
Length of hub, inches	13
Mean pitch as set (*Shubrick*), feet	9.08
Greatest width of blade, inches	21⅞
Helicoidal area each screw, square feet	10.3
Projected area, square feet	7.59
Disc area, square feet	25.22
Pitch ÷ diameter	1.29
Helicoidal area ÷ disc area	.408
Projected area ÷ disc area	.31
Weight one propeller, complete, pounds	880

Boilers.—There are three Thornycroft water-tubular boilers of the Speedy type. In this type of boiler there is one steam drum situated at the apex of an equilateral triangle and two water drums, one at each of the lower angles. The steam drum is connected to each of the water drums by a number of curved tubes for the generation of steam. The steam drum is also connected to the water drums by two large down-take pipes, situated at the front of the boiler. The grate bars are of steel, in groups of six. The back and front of the furnace is built up to the arch of the tubes with fire brick, and on each side to the joint of the tubes with the water drum; each boiler is bolted to angle irons, which are riveted to the saddles. The boiler is covered with a casing consisting of ¼-inch sheet asbestos, and outside of that a 1-inch sheet of non-conducting material, the whole protected by sections of light galvanized steel plate, of such size as to be easily removable while the boiler is in place. There is but one furnace to a boiler, the shape of which is fixed by the arch of the tubes; there are three doors to a furnace. In the steam drum is a Thornycroft automatic feed regulator, which is operated by the variation in the height of the water. The circulation of the water is up the small curved tubes to the steam drum and then

down the two large tubes to the water drums. Each boiler has two 3½-inch safety valves, placed on the stop-valve nozzles, the two valves being in one case.

There is a fire extinguisher situated over each furnace. The boiler tubes are of solid-drawn steel. The boilers are placed fore and aft in two watertight compartments. There are two boilers in a single compartment forward of the engines and one boiler in a compartment abaft the engines, this latter boiler being located over the shafting. There are three smoke pipes, one for each boiler.

BOILER DATA.

Steam pressure, designed, pounds	250
Number of boilers	3
Length of steam drum, feet	10
Width over casing, feet and inches	10– 8
Height, feet and inches	10– 4
Steam drum, diameter inside, inches	30
thickness, inch	¾
Water drums, diameter inside, inches	16
thickness, inch	⅝
Furnaces, width grate, feet and inches	6– 9
length grate, feet and inches	6– 9
Number of furnace doors	3
Tubes, diameter, inches	1⅝ and 1¼
number, 1⅝	776
1¼	140
thickness	No. 11 B.W.G.
Heating surface tubes, one boiler, square feet	2,516
Grate surface, one boiler, square feet	45.6
Ratio, H.S. to G.S.	1 : 55.2
Smoke pipes (3), diameter (oval), inches	39 by 24½
area, each, square feet	5.74
three, square feet	17.22
Height above lower grate, feet	20
Safety valves (2), diameter, inches	3½
Main stop valve, diameter, inches	5½
Total for three boilers, heating surface, square feet	7,548
grate surface, square feet	156.8

Forced Draft.—The closed fire-room system of forced draft is used. The air is supplied by three blowers, made by W. D. Forbes, two in the forward, and one in the after fire room. The fans are driven by simple enclosed engines, set horizontally.

Cylinders (2), diameter, inches	4
Stroke, inches	3
Fan, diameter, inches	42
number of vanes	6
width at rim, inches	14
area of induction nozzle, square inches	706
area of eduction nozzle, square inches	1,847
Revolutions to maintain air pressure of 4½ inches	700

Feed Pumps.—There are two main and one auxiliary feed pump of the Blake vertical, single-cylinder type, all of the same size, 10 inches by 6 inches by 12 inches. The main feed pumps are located, one in the after engine room and one in the forward fire room, and draw from the feed tanks, the reserve feed tanks and air-pump suctions, and deliver to the boilers and reserve-feed tanks. The auxiliary feed pump is situated in the forward engine room and draws from the feed tanks, reserve feed tanks, the sea, the drainage system and boilers, and discharges into the boilers, the fire main and overboard.

Fire and Bilge Pumps.—In the after engine room there is a Blake vertical, single-cylinder pump, which draws from the sea, bilge and drainage system, and delivers into the fire main and overboard. The steam cylinder is 10 inches, the water cylinder 7 inches, and the stroke 12 inches.

Water-service Pump.—The distiller pump in the after fire room is used for this purpose. The water service can also be taken from the condenser.

Feed Tanks—There is a feed tank of 64 gallons capacity in each engine room, from which the water flows by gravity to the pumps. A part of the tank is fitted as a filter, into which water from the air pumps is delivered. The water descends through the filtering material and discharges into the main portion of the tank; each tank has a hinged lid and a glass water gage. Each tank and filter has the following pipe connections:

A discharge pipe from the air pump, an overflow pipe to the bilge, a suction pipe to feed pump, a vapor pipe and drain pipe from traps.

Steam Traps.—The separators, jackets, main and auxiliary steam pipes, steam-heating system and all places where con-

densed steam can accumulate, are fitted with drain pipes and cocks, or valves, and with automatic traps, which discharge into the feed tanks. The traps are provided with by-pass pipes and valves for convenience in overhauling.

Steam Ejectors.—There is a steam ejector in each engine and fire room for freeing the bilge of oil or water. They have a capacity of 2,000 gallons per hour.

Distilling Apparatus.—In the after fire room, there are two evaporators and one distiller of the Baird-Davidson type, with a combined capacity of 2,000 gallons of potable water in 24 hours at a temperature of 90 degrees Fahrenheit. The distillers are arranged so that they can take steam from the auxiliary pipe in case of emergency. There is one distiller pump and evaporator feed pump of the Blake duplex type, 2 inches by $1\frac{1}{4}$ inches by $2\frac{3}{4}$ inches. The distiller has 12 square feet of cooling surface, and each evaporator 40 square feet of heating surface.

Steering Engine.—On the floor of the forward conning tower is a combined hand and steam steering engine made by the Hyde Windlass Co., of Bath, Me. The engine has cylinders $3\frac{1}{2}$ inches diameter and $3\frac{1}{2}$ inches stroke; is of a horizontal type, with the wheel standard directly above it, the shaft of which connects with a pinion of the engine. A wire rope, $\frac{1}{16}$-inch diameter, connects the quadrant on rudder with the steering engine in the forward conning tower and also with the hand-steering gear in the after conning tower. The engine responded very promptly to the movement of the wheel.

Steam Windlass.—The steam windlass was built by the Hyde Windlass Co., and is situated directly abaft the collision bulkhead. The engine is of the reversible, double-cylinder, horizontal type, with cylinders $3\frac{1}{4}$ inches diameter and 4 inches stroke, and connects with the drums by means of a spiral gear and pinion. The two drums, which are placed athwartships, are made for wire cable, and have a capacity of 75 fathoms of $\frac{9}{16}$-inch diameter wire rope. On the turtleback is a capstan connected with the windlass below through a vertical shaft.

Air Compressor.—There is one air compressor for the torpedoes situated in the starboard engine room. It is the Bliss type 1–A,

and on trial, with 150 pounds boiler pressure, supplied air at 1,500 pounds pressure in seven minutes throughout the entire torpedo outfit of piping.

Telegraph and Revolution Indicators.—There is a Cory mechanical telegraph in each engine room connected to transmitters in forward and after conning towers. Mechanical tell-tales are fitted in the forward conning tower to show the direction and speed of revolutions of the main engines. In each engine room there is a mechanical revolution counter.

Voice Tubes.—For communication between the conning towers, torpedo-tube stations and engine rooms, there are voice tubes with electric call bells.

Electric Plant.—The installation consists in general of one 2½-kilowatt generating set, sixty incandescent lights, one searchlight, one set of signalling apparatus, one main switchboard, together with the necessary wiring, wiring accessories, conduits and fixtures.

The generating set was made by the General Electric Co., and consists of one 2½-kilowatt dynamo of multipolar type with a capacity of 31 ampères at 80 volts, compound wound, six poles. The dynamo engine is of the single-cylinder, vertical type; diameter of cylinder, 2 inches by 3-inch stroke. The engine is designed to run under full load at 800 revolutions per minute with 80 pounds steam pressure. The bedplate is common to both engine and dynamo. The incandescent lights are of 5 and 16 candlepower, designed for a potential of 80 volts. The dynamo is connected to the switchboard through suitable leads protected by steel conduits. The switchboard is equipped with one main dynamo switch and three circuit switches, two Weston round-pattern switchboard voltmeters, together with the usual rheostats, pilot lamps and ground detectors. The vessel is wired on the two-wire system.

There is one 12-inch hand-controlled searchlight, made by the General Electric Company, mounted on the forward conning tower and in circuit with a suitable rheostat mounted on the main switchboard.

Annunciators, press buttons and bells, are provided in connec-

tion with the speaking tubes for communication between the conning towers and the various compartments of the vessel.

MACHINERY WEIGHTS (IN TONS OF 2,240 POUNDS).

	Dry.	*Wet.*
Engine-room and stern weights	35.75	39.03
Forward fire-room weights	25.61	29.40
After fire-room weights	13.07	15.02

SUMMARY.

Engine-room and stern weights	35.75	39.03
Fire-room weights	38.68	44.42
Total	74.43	83.45
Tools, stores, etc		2.91
Distilling and heating plants		2.45
Total weight		88.81

DETAILED WEIGHTS FOR ONE ENGINE.

Cylinders and fittings, tons	3.14
Shafting, tons	3.58
Reciprocating parts, tons	.81
Framing, bed plates and bearings, tons	2.95
Valves and valve gear, tons	.70
Condensers, tons	1.78
Air and circulating pumps, tons	.55
Boiler, fittings and uptakes (one boiler), tons	9.7
Smoke pipe	.19

FOR ONE BOAT.

Steam, exhaust, suction, discharge pipes and valves, tons	5.82
Lagging and clothing, tons	5.53
Floor plates, tons	1.25
Auxiliaries, tons	2.71
Fittings and gear, tons	2.07

The average tensile strength of the various materials used on these boats is as follows:

	Tensile.	*Minimum elastic limit.*
Forged steel:		
Engine, main parts, except crank shaft	95,000	65,000
Columns, stays, pistons	80,000	50,000
Handgear, etc	80,000	45,000
Ordinary forgings	60,000	30,000
Cast steel:		*Per cent. elongation in 8 inches.*
Subject to shock	60,000	15
Not subject to shock	70,000	10
Composition, 88 Cu. 10 Zn. 2 Sn	34,000	14
Brazing metal, 90 Cu. 2 Zn. 8 Sn	28,000	20

	Tensile.	*Minimum elastic limit.*
Manganese-bronze	70,000	40,000
Copper pipe, hydraulic test	6,000	.....
Brass pipe, hydraulic test	7,000	.....
Tobin bronze, rolled rods	60,000	30,000
Phosphor-bronze, rolled rods	40,000	.....

THE TRIALS.

The official trials of the *Shubrick* and *Thornton* were held on the Barren Island course, fifty miles below Annapolis, Maryland, the boats leaving on alternate days.

Each boat was required to undergo two trials; the first, a standardization screw trial, and the second, a two-hour run at full speed, at the average number of revolutions necessary for a speed of 26 knots, as determined by the standardization of the screw on the previous trial.

The engineers and firemen were thoroughly experienced in this class of work, and were under the supervision of Mr. Geo. F. Coleman, who had conducted the trial of the *Stockton*, a sister boat, built by the William R. Trigg Company, and the first of the torpedo boats built under the Act of Congress of 1898 to be accepted by the Navy Department.

No indicator diagrams were taken from the *Shubrick's* engines.

Both boats had passed the preliminary trials of the contractors very successfully about two weeks before on the Government measured mile in Chesapeake Bay off Cape Charles City.

The progressive-speed trials of the *Shubrick* for the standardization of the propellers, over the measured-mile course, commenced at 3.20 P. M., April 2, 1901, and lasted about one and one-half hours.

The conditions of wind and sea were favorable. The several double runs were made as nearly as practicable at the rates of speed prescribed by the precept for the trial. At a signal given by the observer, who marked with a stop watch the time of passing the range marks placed at the ends of the measured-mile course, the two counters were thrown into gear at the moment of entering and out of gear at the moment of leaving the course. Readings of the engine-room gages were taken and recorded during each run. Table I gives the data observed in the engine

rooms and at the counters on deck for each run over the measured mile. The points obtained from the observed revolutions of the engines and the corresponding speeds of the vessel on the measured mile were used to determine the revolutions necessary for a speed of 26 knots.

The trials were conducted by the Naval Board of Inspection and Survey, composed of Rear Admiral Robley D. Evans, President; Captain Joseph N. Hemphill, Naval Constructor J. J. Woodward, Commander Charles R. Roelker, Lieutenant Commander Charles E. Vreeland, and Lieutenant Commander Thomas S. Rodgers, Recorder.

DATA OF STANDARDIZATION TRIAL OF *SHUBRICK*.

Draught at beginning of trial, forward, feet and inches	4– 8
aft, feet and inches	7– 2
mean, feet and inches	5–11
ending of trial, forward, feet and inches	4– 4
aft, feet and inches	7– 0
mean, feet and inches	5– 8
Displacement at beginning, tons	193.5
ending, tons	179.5

Above was read from mean of salt and fresh-water curves and draughts taken at Annapolis before starting and after returning, respectively.

TABLE I.—STANDARDIZATION TRIAL OF *SHUBRICK*.

	1st Double run.		2d Double run.		3d Double run.		4th Double run.	
Direction of run	N.	S.	N.	S.	N.	S.	N.	S.
Duration of run	3m. 0.1s	3m. 4.9s	2m. 59.4s	2m. 35.8s	2m. 24.1s	2m. 24.3s	2m. 16.8s	2m. 17.1s
Mean speed of vessel in knots	19.73		22.85		24.96		26.22	
Total revolutions each run by counters, starboard	842	859	855	848	853	846	865	852
port	797	814	818	820	819	818	822	809
Mean revolutions per minute during double run	271.55		318.05		347.00		365.80	
Mean slip of screws	18.9		19.4		19.7		20.06	
Steam pressure above atmosphere, main steam pipe, port	117	118	184	190	220	221	253	255
starboard	122	118	172	186	222	221	255	258
Ditto, 1st receiver, port	35	35	60	60	75	77	90	87
starboard	40	38	60	62	77	75	90	90
Ditto, 2d receiver, port	5	5	3	4	7.5	7.5	10	16
starboard	0	0	5	5	10	10	14	12
Vacuum in inches of mercury, port	25	25	23	24	23	23	20.5	22.5
stb'd	26.5	27	25	25.5	25	25	24	24.5

The points obtained from the observed revolutions of the engines and the corresponding speeds of the vessel on the measured mile being plotted, gave very satisfactory fair curves, and the mean engine speed required for a speed of 26 knots of the vessel deduced from these curves was found to be 362.1 revolutions per minute.

Early in the forenoon of April 5, 1901, the *Shubrick* left Annapolis for the purpose of running the full two-hour contract-speed trial. The conditions of wind and sea were favorable.

The trial lasted exactly two hours. The counter readings were recorded every five minutes, and the engine-room gages were read every fifteen minutes. The observed data are given in the two following tables. The air pressure in the after fire room ran up to about seven inches of water during the early part of the run, causing the water to be blown out of the gage and preventing further readings.

The coal used during the full-power speed trial was hand-picked Pocahontas of excellent quality, supplied to the fire room in bags weighed by the contractors. The quantity of coal consumed per hour was 13,000 pounds.

DATA TWO-HOUR TRIAL RUN *SHUBRICK*.

Hull weights to date, pounds	170,978
Steam engineering weights, not including water in pipes, condensers and boilers, pounds	172,418
Ordnance weights, including air-compressing plant and piping, pounds	2,051
Articles comprising equipment within the meaning of the contract, pounds	6,323
Water in condensers, pipes and boilers, pounds	20,500
Reserve feed water, pounds	16,065
Total, pounds	388,335
Put on board for trial:	
Coal	31,000
Men	6,750
Provisions, temporary outfit, oils, etc	850
Total, in pounds	426,935
Or in tons	190.6
Draught at beginning of trial, forward, feet and inches	4– 8½
aft, feet and inches	7– 0½
mean, feet and inches	5–10½
Displacement from curves, tons	192.5
Draught at end of trial, forward, feet and inches	4– 7
aft, feet and inches	6–11
mean, feet and inches	5– 9
Displacement from curves, tons	184.5
mean for trial, tons	188.5

Mean of readings of fresh and salt-water curves. A measurement of the density of the water at Annapolis had shown the amount of salt to be one-half of normal.

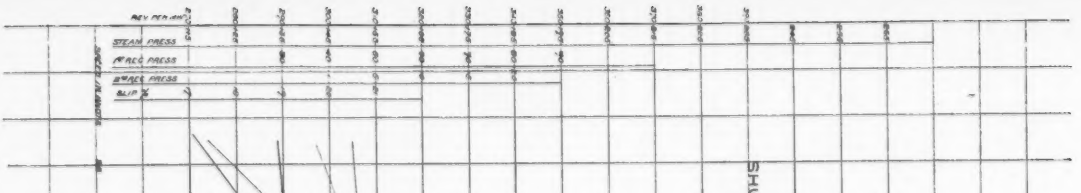
TABLE II.—*SHUBRICK*, STARBOARD ENGINE.

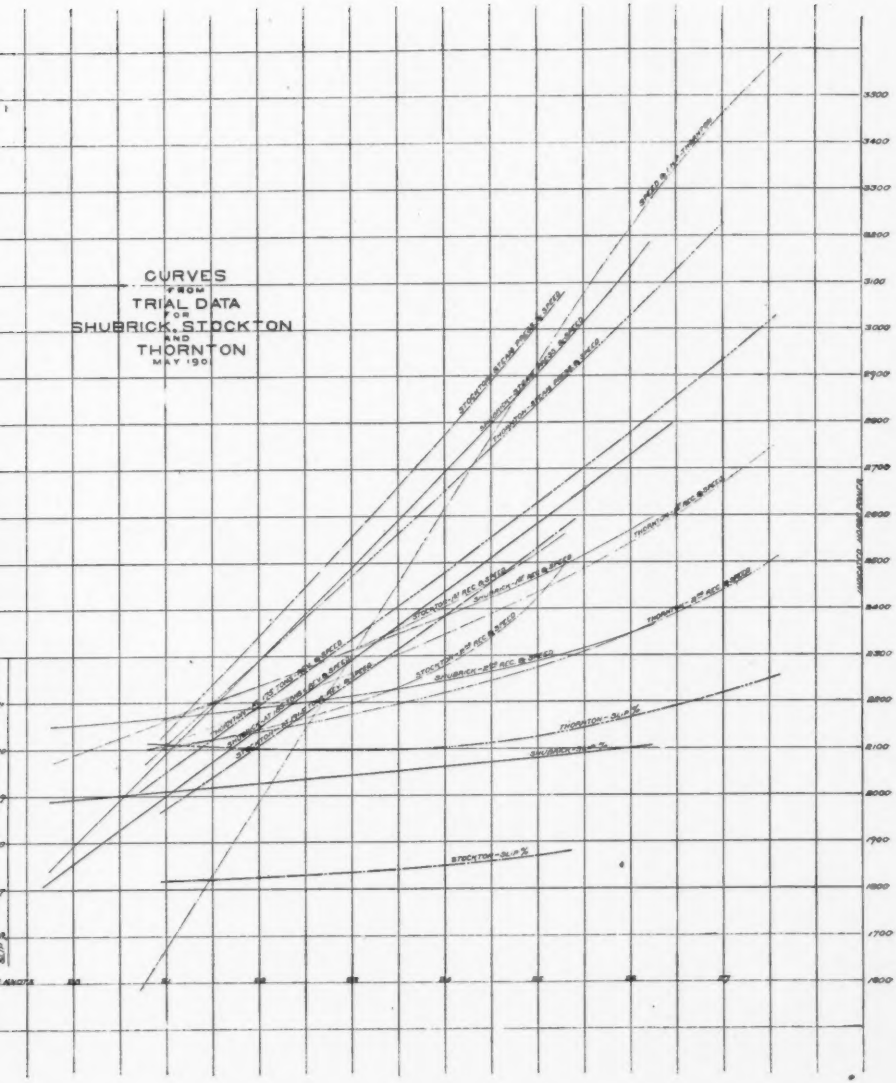
Time, A. M.	Counter.	Rev. per minute.	Steam pressures above atmosphere.			Vacuum.	Air pres. in for'd fire room, inches.
			Steam pipe.	1st Receiver.	2d Receiver.		
9 h. 45 m.	19,460	.....	255	89	14	23.8	4
10 00	25,065	373.7	250	89	13	23.5	3
10 15	30,660	373.0	250	89	13	23.0	4
10 30	36,285	375.0	250	89	13	24.0	2
10 45	41,900	374.3	255	89	13	24.0	2
11 00	47,515	374.3	260	90	13	24.0	2.5
11 15	53,075	370.7	255	92	13.5	23.5	3
11 30	58,760	379.0	255	92	14	23.5	2
11 45	64,390	375.3	260	90	13	23.0	3
Mean.....	.....	374.4	254.4	90	13.3	23.9	2.83

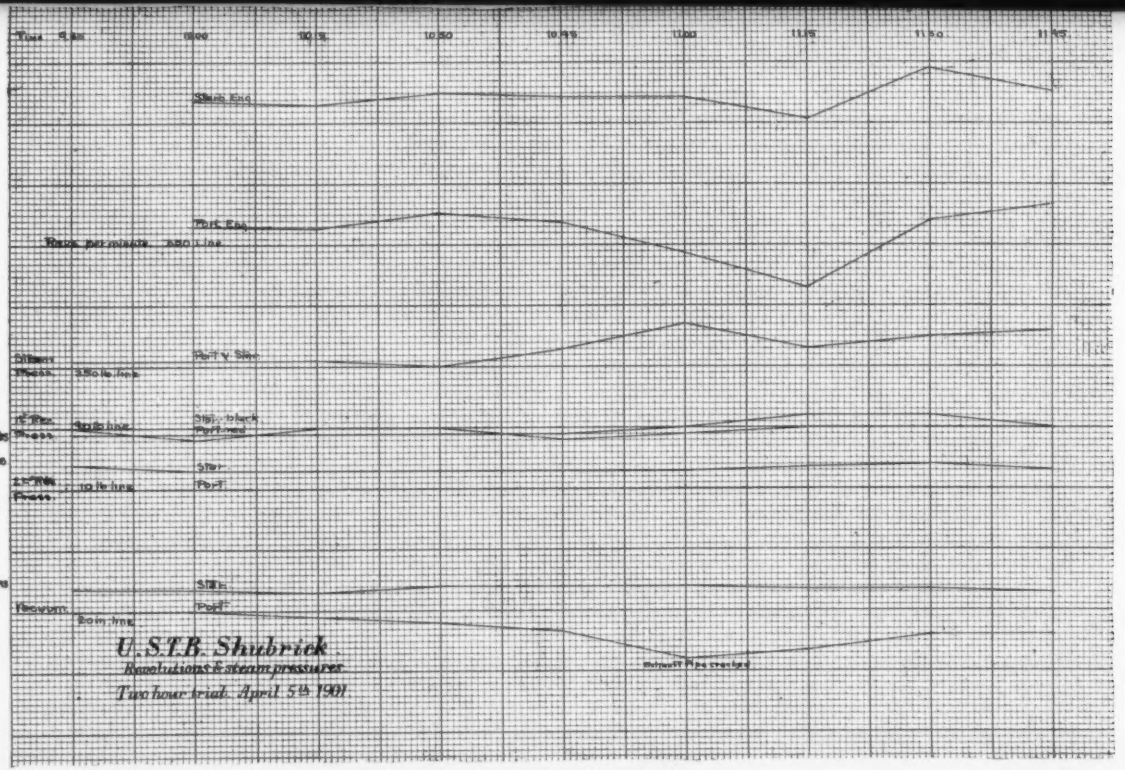
TABLE III.—*SHUBRICK*, PORT ENGINE.

Time, A. M.	Counter.	Rev. per minute.	Steam pressures above atmosphere.			Vacuum.	Air pres. in after fire room, inches.
			Steam pipe.	1st Receiver.	2d Receiver.		
9 h. 45 m.	124,300	.....	247	90	10	20.0	5
10 00	129,595	353.0	252	88	10	20.0	6
10 15	134,885	352.7	252	90	10	19.0	...
10 30	140,215	355.3	249	90	10	18.0	...
10 45	145,520	353.7	252	88	10	16.5	...
11 00	150,750	348.7	254	89	10	12.0	...
11 15	155,895	343.0	252	90	10	13.5	...
11 30	161,205	354.0	255	90	10	16.0	...
11 45	166,555	356.7	252	90	10	16.0	...
Mean.....	.....	352.1	251.7	89.4	10	16.8	...

The official report of the speed for two hours was 26.07 knots, at an engine speed of 363.27 revolutions per minute. After the two-hour speed trial, the steering engine was tested by putting the helm from amidship to hard-a-port, the time taken being 2.4 seconds; and from hard-a-port to hard-a-starboard in 4.8 seconds. The speed of the vessel before putting the helm over was 20 knots. The list with full helm was $7\frac{1}{2}$ degrees, the diameter of the turning circle approximating 100 fathoms. The curves on Plate I show the comparative speed, revolution and steam pressure for the three boats, *Shubrick*, *Stockton* and *Thornton;* Plate II the comparative revolutions and steam pressures for the two-hour run of the *Shubrick*.


REV PER MIN
STEAM PRESS
1ST REC PRESS
2ND REC PRESS
SLIP %
SHU


CURVES
FROM
TRIAL DATA
FOR
SHUBRICK, STOCKTON
AND
THORNTON
MAY 1901
3300
3400
3300
3200
3100
3000
2900
2800
2700
2600
2500
2400
2300
2200
2100
2000
1900
1800
1700
1600
THORNTON - OIL IN %
SHUBRICK - OIL IN %
STOCKTON - OIL IN %


Time
10.00
10.15
10.30
10.45
11.00
11.15
11.30
11.45
Revs. per minute
Port Eng.
Port V. Stm.
Stm. Eng.
Stm. Chest
Port
Stm.
Port
Stm.
Port
Vacuum
Boiler
U.S.T.B. Shubrick.
Revolutions & steam pressures
Two hour trial. April 5th 1901.

The standardization trial of the *Thornton* took place at Barren Island, March 29, 1901. This boat made the highest speed of the three, and was the only one on which cards were taken. The following tables give the data of the trials and the cards.

TORPEDO BOAT *THORNTON*, STANDARDIZING SCREW TRIAL—BARREN ISLAND, MARCH 29, 1901.

Mean draught for runs Nos. 7 and 8, 5 feet 7½ inches; actual mean draught of hull, 4 feet 8 inches; displacement, 175 tons; mean pitch of screws, 9.08 feet.

Coal consumption.—(A.) 1¼-inch air pressure, 34.5 pounds per square foot of grate surface; Pocahontas run. (B.) 8-inch air pressure, 95.0 pounds per square foot of grate surface; Pocahontas picked.

SPEED DATA.

Run	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.
Time, hours and minutes	2:54.0	2:52.1	2:31.7	2:27.9	2:23.6	2:18.1	2:13.4	2:7.9
Speed, knots	20.690	20.918	23.731	24.341	25.070	26.068	26.987	28.149
Average speed, knots	20.804		24.036		25.569		27.568	
Revolutions, port	294.80	296 00	339.75	342.00	363.92	367.14	385.49	392.67
starboard	287.25	291.10	330.62	335.10	353.50	361.90	393.55	398.75
average	291.03	293.55	335.19	338.55	358.71	364.52	389.52	395.71
Aver. revolutions of runs	292.29		336.87		361.61		392.61	
Slip per cent., port	23.73	22.20	23.20	21.65	24.16	21.81	22.92	21.08
starboard	17.75	17.94	18.00	17.07	19.00	17.74	21.68	19.37
average	20.24	20.06	20.60	19.36	21.58	19.77	22.30	20.22
average of runs	20.15		19.98		20.68		21.26	
Tide and wind	Against.	With.	Against.	With.	Against.	With.	Against.	With.

POWER DATA.—*Port Engine.*

Main steam	140	140	200	200	230	230	268	263
First receiver	40	40	63	65	80	70	100	100
Second receiver	0	1	5.5	6	10	12	18	22
Vacuum	23	26	25	23	23	20	20	15
M.E.P., H.P.	60.2	61.7	85.7	87.2	94.3	91	90.4	.....
I.P.	28.3	28 8	38.3	38	44.1	45.8	53.4	.....
L.P.	9	10.2	12.5	13.5	16.3	16.5	17.5	.....
L.P.	9.2	9.7	13.6	13.3	16.5	16	17.5	.....
total	28.92	30.2	40.5	41	47.4	47.4	51.4	50.1
I.H.P., H.P.	242.8	249.8	398.4	408	469.4	456.9	476.7	.....
I.P.	285.6	291.9	445.5	445	549.4	575.6	704.8	.....
L.P.	119.7	136.5	192	208.7	268.1	273.8	304.9	.....
L.P.	122.6	129.8	208.9	205.6	271.4	265.5	304.9	.....
total	770.7	808	1,244.8	1,267.3	1,558.3	1,571.8	1,791.3	1,778.3

Starboard Engine.

Main steam	135	135	200	200	235	225	268	263
First receiver	38	40	65	65	80	75	115	105
Second receiver	1	1	6	6	10	10	20	23
Vacuum	26	26	25	24.5	24	22.5	18.5	17
M.E.P., H.P.	72 9	.....	97	98.8	111.7	.....	.....	.....
I.P.	26.3	.....	39.3	41.0	45.4	.....	.....	.....
L.P.	10	.....	14.3	13.8	14.7	.....	.....	.....
L.P.	9.7	.....	14.3	13.8	14.7	.....	.....	.....
total	30.8	30.8	43.9	44.3	48.8	47	50	50
I.H.P., H.P.	286.5	.....	438.7	452.9	540.1	.....	.....	.....
I.P.	258.7	.....	444.9	470.4	549.5	.....	.....	.....
L.P.	129.9	.....	213.7	209	234.8	.....	.....	.....
L.P.	126.0	.....	213.7	209	234.8	.....	.....	.....
total	801.1	810.5	1,311	1,341.3	1,559.2	1,537.6	1,779	1,802.5

Port and Starboard Engines.

Total both	1,571.8	1,618.5	2,555.8	2,608.6	3,117.5	3,109.4	3,570.3	3,580.8
Average of runs	1,595.1		2,582.2		3,113.5		3,575.5	

The cards showing friction of engines were taken on the trip down James River, under the following conditions:

The engines and shafting were coupled, but the propellers were not in place. The air and circulating pumps were working, the air pumps being connected and worked from the line shafting.

DATA OF TRIAL.

Draught at beginning of trial, forward, feet and inches	4- 7
aft, feet and inches	7- 0
mean, feet and inches	5- 9½
Displacement, tons	187
Draught at end of the trial, forward, feet and inches	4- 4
aft, feet and inches	8-11
mean, feet and inches	5- 7½
Displacement, tons	174

the trip

ropellers
working,
shafting.

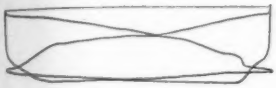
..... 4– 7
..... 7– 0
..... 5– 9½
..... 187
..... 4– 4
..... 8–11
..... 5– 7½
..... 174

INDICATOR DIAGRAMS, FRICTION TEST, PO

NOTE.—Diagrams show power required to overcome friction of engine, sh

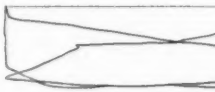
Spring 20

Run No. 1—H.P.



Run No. 2—H.P.

Run No. 3—H.P.

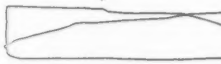


Spring 10

Run No. 1—I.P.

Run No. 2—I.P.

Run No. 3—I.P.



Spring 8

Run No. 1—L.P.

Run No. 2—L.P.

Run No. 3—L.P.

Revolutions	150
M.E.P., H.P.	4.9405
I.P.	2.3825
L.P.'s	1.1059
total	2.7560
I.H.P., H.P.	10.1370
I.P.	12.2360
L.P.'s	14.9950
total	37.3680

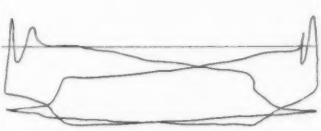
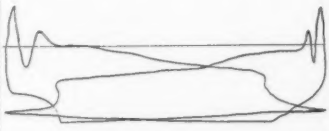
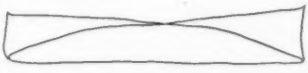
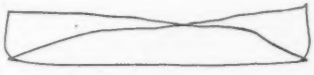
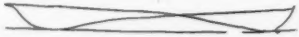
Revolutions	208
M.E.P., H.P.	4.942
I.P.	2.299
L.P.'s	.941
total	2.559
I.H.P., H.P.	14.062
I.P.	16.371
L.P.'s	17.690
total	48.123
with screw	230
Per cent. of friction	20.92

Revolutions	
M.E.P., H.P.	
I.P.	
L.P.'s	
total	
I.H.P., H.P.	
I.P.	
L.P.'s	
total	
with screw	
Per cent. of friction	

FULL SPEED.—Revolutions, 386; I.H.P., 1,780; I.H.P.,

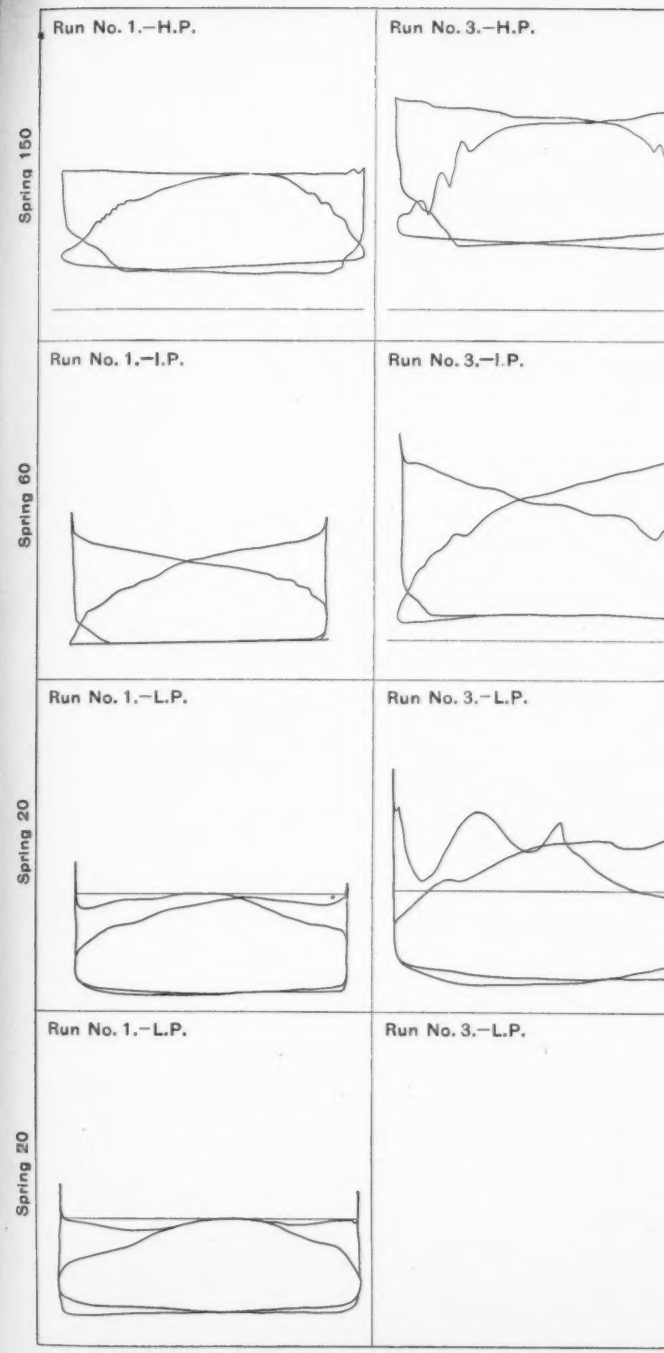
TEST, PORT ENGINE OF "THORNTON."

of engine, shafting and air pump; work of air pump is also included.

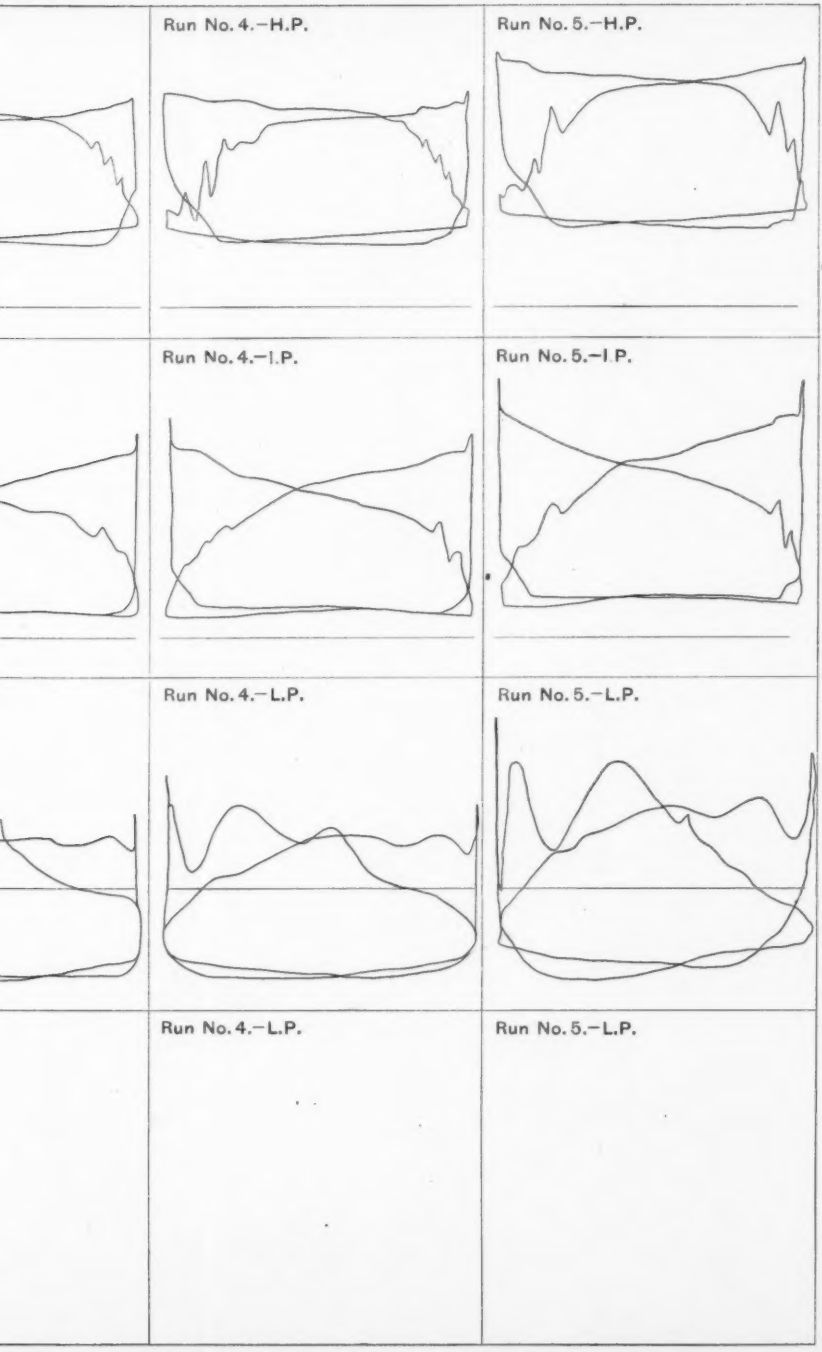
.P.	Run No. 4–H.P. 	Run No. 5–H.P. 
P.	Run No. 4–I.P. 	Run No. 5–I.P. 
P.	Run No. 4–L.P.	Run No. 5–L.P. 

s..... 230	Revolutions..... 270	Revolutions..... 300
P..... 5.172	M.E.P., H.P..... 5.838	M.E.P., H.P..... 5.631
..... 2.457	I.P..... 2.358	I.P..... 2.280
P.'s..... .800	L.P.'s..... .914	L.P.'s..... 1.097
tal..... 2 513	total 2.690	total..... 2.813
.P..... 16.273	I.H.P., H.P..... 21.564	I.H.P., H.P..... 23.11
..... 19.352	I.P..... 21.800	I.P..... 23.42
P.'s..... 16.633	L.P.'s..... 22.306	L.P.'s..... 29.75
al..... 52.258	total..... 65.670	total..... 76.28
th screw..... 330	with screw..... 580	with screw..... 825
f friction..... 15.84	Per cent. of friction..... 11.32	Per cent. of friction..... 9.25

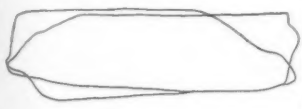
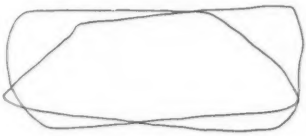
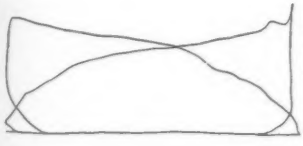
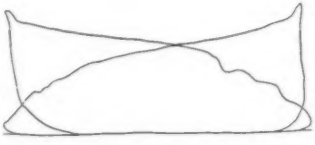
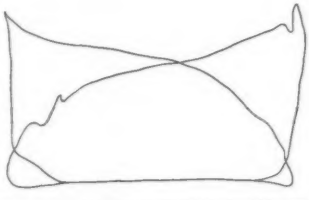
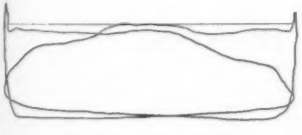
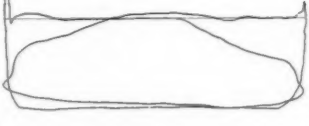
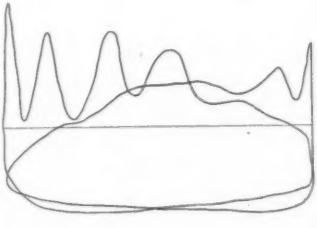
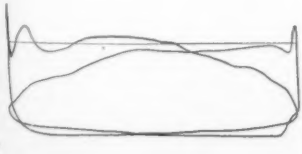
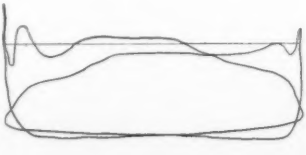
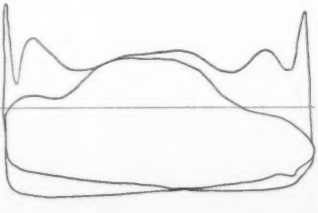
,780; I.H.P., friction, 115; per cent. of friction, 6.46



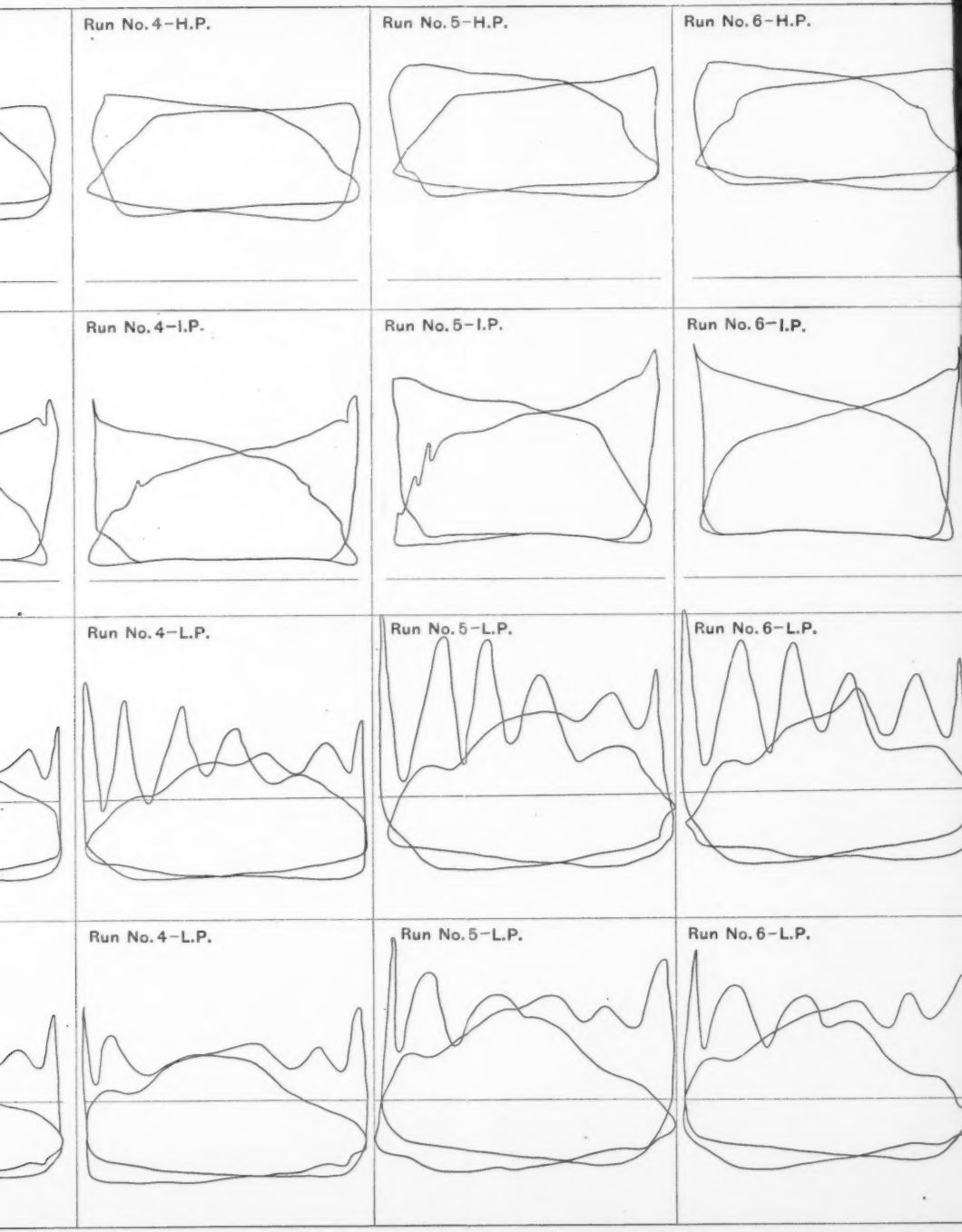
STANDARDIZATION SCREW TRIAL OF THE "TH



THE "THORNTON," MARCH 29, 1901. STARBOARD ENGINE.

Spring 150	Run No.1–H.P. 	Run No.2–H.P.	Run No. 3–H.P. 
Spring 60	Run No. 1–I.P. 	Run No. 2–I.P. 	Run No. 3–I.P. 
Spring 20	Run No. 1–L.P. 	Run No. 2–L.P. 	Run No. 3–L.P. 
Spring 20	Run No. 1–L.P. 	Run No. 2–L.P. 	Run No. 3–L.P. 

STANDARDIZATION SCREW TRIAL



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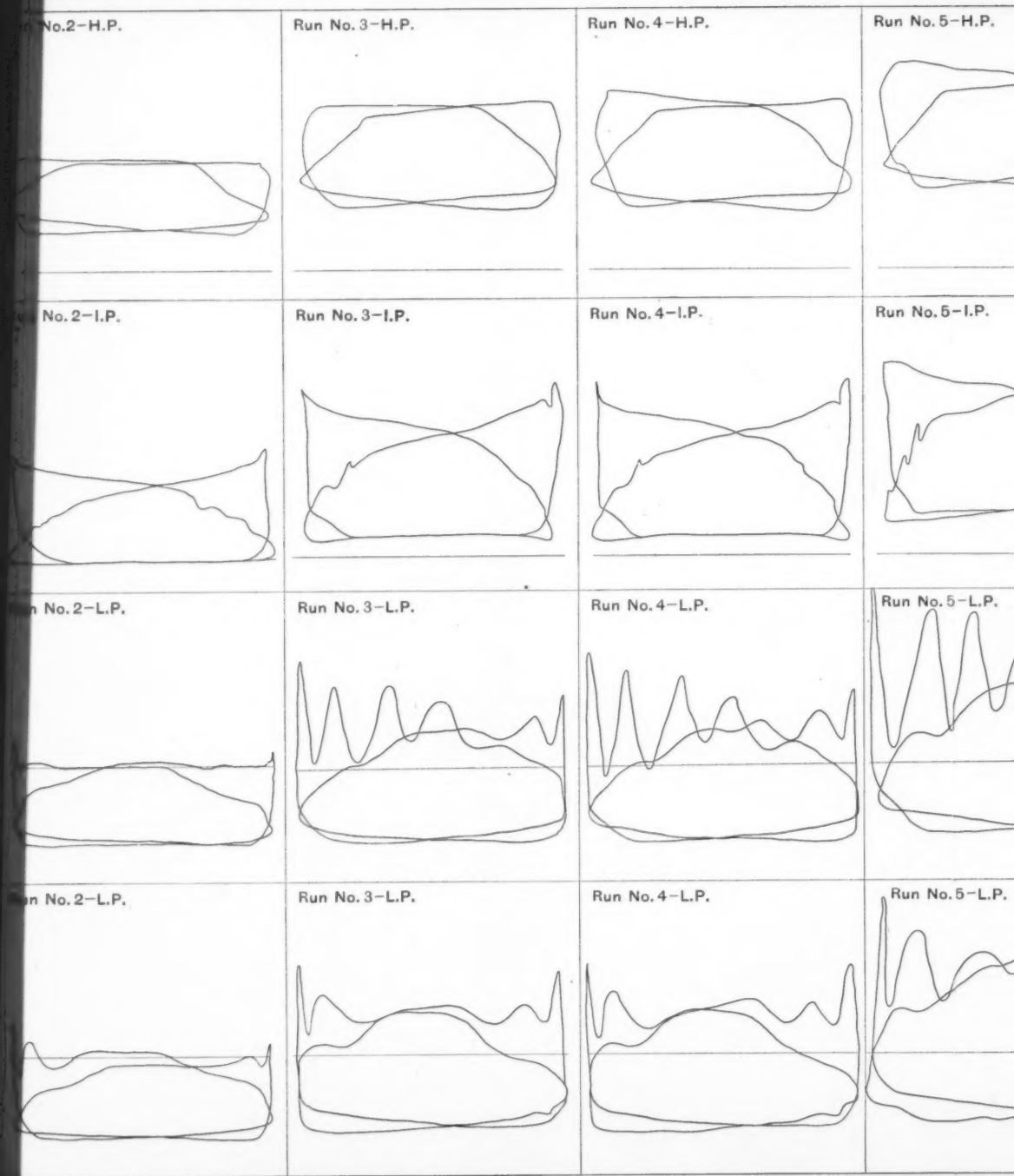

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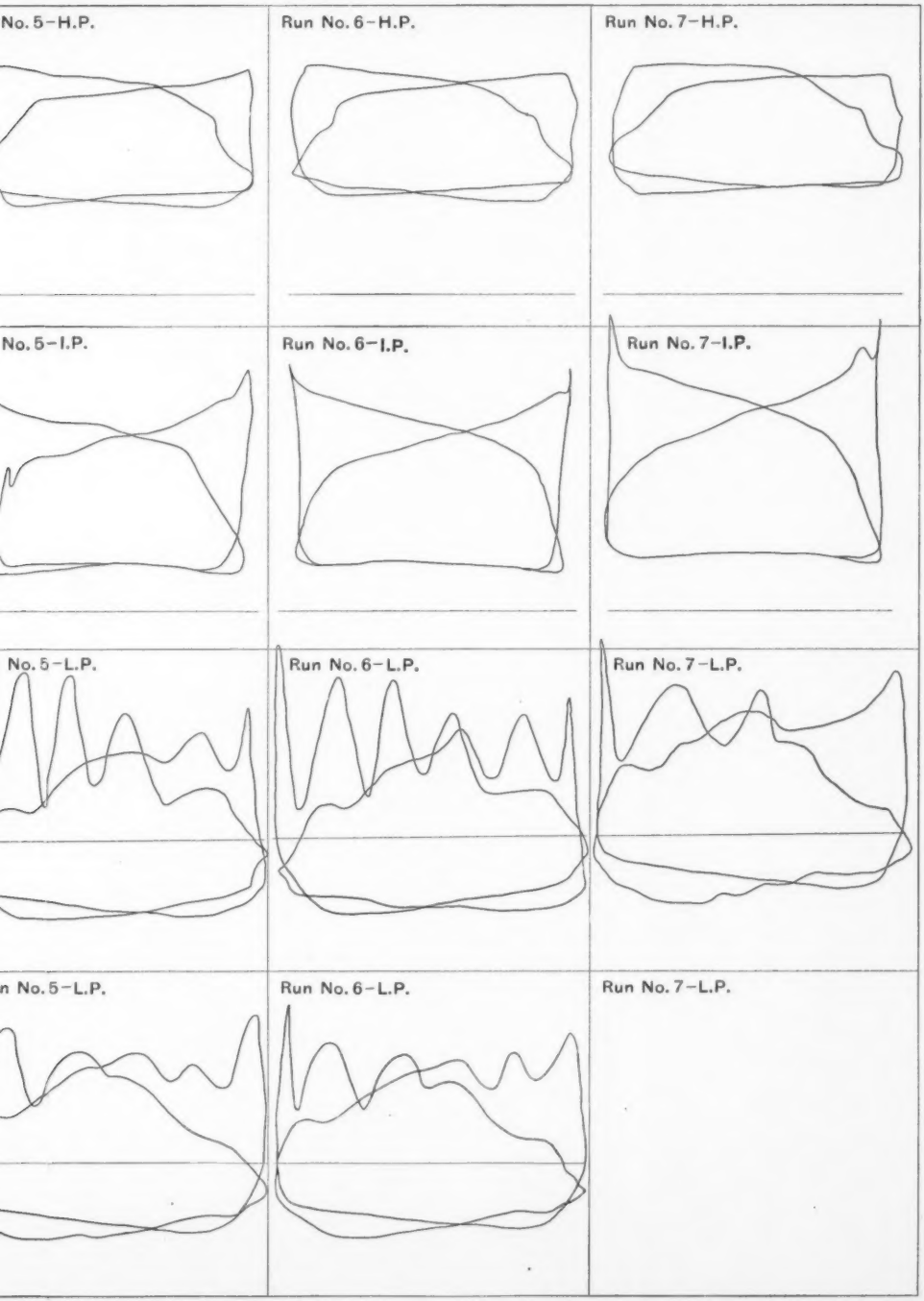


29, 1901. PORT ENGINE.

MERCANTILE AUXILIARIES.

[Paper read before the Institution of Naval Architects.]

By the Right Hon. Lord Brassey, K.C.B., D.C.L.

In bringing forward proposals for a more vigorous policy in relation to mercantile auxiliaries, I return to a subject in which, following the lead of Sir Nathaniel Barnaby and other authorities, I have long been deeply interested.

The history of the question may be briefly traced. The earliest contracts for the conveyance of the mails required that postal vessels should be suitable for conversion into armed cruisers. In 1853, upon the recommendation of the Committee on Postal Contracts, those wise stipulations were withdrawn. It is a notable circumstance that, at the same date, iron was condemned as a material for the construction of fighting ships. After the lapse of a quarter of a century, the subject was taken up by Sir Nathaniel Barnaby. His views were presented for the consideration of this Institution in a paper, read in the session of 1877, on the fighting power of the merchant ship. Sir Nathaniel Barnaby insisted on the impossibility of providing adequately for the protection of our vast commerce with regularly-built vessels of war. It was impossible to say what number of fast cruising ships would be sufficient for England, seeing that we should never know in what part of the world we should be attacked. It was necessary, therefore, to supplement—and largely to supplement—our regular cruisers with auxiliary vessels. Sir Nathaniel Barnaby's recommendations found powerful supporters.

Admiral Sir Frederick Gray spoke as follows: "Having been at the Admiralty, and having felt the difficulty of providing, even in peace time, the force necessary to fulfil the various duties devolving on our ships of war, I think it would be utterly impossible to provide sufficient protection for our mercantile marine in time

of war. I believe that the merchant steamers of England, if strengthened and fitted as proposed by Mr. Barnaby, would be very useful. I do not say that they would take the place of men-of-war, but they would be most useful as auxiliaries." In the same discussion Sir Spencer Robinson, then the Comptroller of the Navy, expressed himself in these words: "Those splendid ships which pass between the United States and England with very great speed and a coal-carrying capacity far exceeding the coal-carrying capacity you can give to any unarmored man-of-war, could be made capable of carrying such an armament as would protect them from the attacks of vessels of a similar class to their own."

These views of the naval advisers of the Admiralty, vainly urged a generation ago, have been fully shared, and practically adopted, by the naval advisers of foreign Powers. I may quote the remarks of Admiral Fournier, in his able pamphlet, entitled, "La Flotte nécessaire." "As types of fast cruisers for the destruction of commerce, I know of nothing which more fully meets the requirements than those magnificent transatlantic steamships, the *Lucania* and *Campania*, capable of maintaining a speed of 22 knots an hour, with extraordinary uniformity. The *New York*, *Paris*, *St. Louis* and *St. Paul*, and the English ships *Majestic* and *Teutonic* possess the same qualities, though in a somewhat less degree of perfection. Such ships will, in my view, be the destroyers of commerce in the future."

While their chief naval and technical advisers were endeavoring to obtain the assent of the Board of Admiralty to some practical action, the subject was not neglected out of doors. In 1878 a paper was published in the "Nautical Magazine" by the late Lord Inverclyde. I quote his weighty words, as true to-day as when they were written: "There never was a time in the history of this country when the subject of the efficiency of the Royal Navy occupied a position of greater importance than it does at present. Our risks lie in the fact that the fleets of other nations are fast becoming powerful and reliable; and whilst no navy can numerically approach that of this country, yet there are nations in Europe whose fleets combined would undoubtedly

give us enough to cope with. How then can we stride ahead as the greatest maritime Power, and hold our own against the fleets of the world? Not by being satisfied with increasing the strength of the Navy proper, which, owing to the prodigious cost of modern war vessels, can only be done in a comparatively small degree. But what cannot be accomplished in that direction can be attained by other means ready to our hand, and that by utilizing the vessels of the mercantile marine."

At the date of Lord Inverclyde's paper the cost of our most powerful cruisers was under a quarter of a million. The cost of the first-class cruisers we are now building is more than threefold greater. The practical steps which Lord Inverclyde recommended to the Admiralty are briefly described in his paper. There was wanted a scheme by which the advantages of the vast fleet of merchant steamers now belonging to the country should be conserved for our special requirements, and it was due to our naval authorities to admit that they had recognized that there were numerous British vessels which could easily be converted into cruisers. There was, however, one fatal flaw in the Admiralty plan. They wanted to have the use of the ships without paying an adequate consideration! As Lord Inverclyde put it: "It was not to be supposed that a position for their vessels on the select list would be a sufficient inducement to comply with Admiralty requirements, and to incur the expense involved in exacting the requisite alterations. War being only a contingency more or less remote, a retaining fee must be offered." It was proposed by Lord Inverclyde that subsidized steamers should be built to meet certain requirements, including increased bulkheads and watertight compartments. The ships should be manned by seamen of the Royal Naval Reserve, who should be thoroughly trained in gunnery at the respective home ports of the companies or owners.

The subject of mercantile auxiliaries continued to attract the attention of our highest authorities on naval administration. In 1880 Sir Donald Currie read an exhaustive paper at the United Service Institution. He referred to the general increase in naval preparations. France had increased her Navy; Germany and

Russia were making large strides in the direction of more powerful naval forces. Quite recently the Russian volunteer fleet had been originated by Prince Dologorouki, the Governor General of Moscow. He addressed himself to the wealthy merchants of that ancient capital, appealing to their patriotism, and a volunteer cruisers' fund had been raised. Sir Donald Currie submitted a scheme for the retention of swift merchant cruisers by an annual subsidy.

I may refer to another shipowner, most eminent in that branch of enterprize with which he was connected. I refer to the late Mr. Ismay. In the evidence which he gave before the Royal Commission on coaling stations, he truly said, "when a company has not been doing well, and has got heavy bills running, which it cannot meet, the temptation to shut its eyes to what would be the ultimate destination of ships sold to foreigners in a crisis would be very great. At the commencement of the Russian scare, on the occasion of the Penjdeh incident, great temptations were offered to the owners of the White Star steamers running between San Francisco and Japan, and it was not too much to say that our whole commerce in the Pacific would have been transferred to the flag of the United States if that offer had been accepted." The British ownership of a magnificent steamship is a slight national tie. It binds to no national service while it exists, and it may be broken without warning, at the will of the owners. These considerations may be pleaded as a strong argument in support of the policy of binding all our finest vessels to the service of the State as mercantile auxiliaries.

Passing on to the later authorities, the practicability of so constructing merchant steamers as to render them readily available for war purposes, was discussed by Mr. Biles in a paper read at an engineering conference, held under the auspices of the Institution of Civil Engineers, in June, 1899. Arguing from the results of arming and fighting the mercantile cruisers of the United States Navy, Mr. Biles takes the view that such vessels are not unable to cope with thoroughbred warships. The experiences of modern sea fights point to the conclusion that a ship is more liable to be disabled by her crew being driven from their

guns than to be sunk by the effects of shell fire. The issue of a fight between a warship and a merchant ship may not turn on the relative efficiency of the internal subdivision, but on the protection of the guns. By placing the guns in a box battery, as the Americans did, a considerable number of guns could be as well protected in merchant ships as in first-class cruisers. Mr. Biles holds it to be practicable, with due consideration in the early stages of design and construction, to so protect machinery and armament that the merchant ship need not be much, if at all, inferior to many warships.

The policy of liberal subsidies to the mercantile marine has given to the merchant navies of foreign Powers a decided advantage in the possession of the types of vessels most suitable for naval purposes. The Germans have taken the lead. They have two ships now runnning—the *Deutschland* and the *Kaiser Wilhelm*, of 14,000 tons and 15,000 tons, respectively—which exceed in speed by nearly 2 knots our best ships. No vessel now building for the British flag will rival in speed the *Kaiser Wilhelm II* and *Kronprinz Wilhelm* under construction in Germany.

Of ships capable of a regular sea speed of over 18 knots, France has 4, Germany 8, and Great Britain 10.

Taking vessels above 3,000 tons only, Lloyd's statistics, as quoted by Mr. Biles, give the relative positions as follows:

	British.	Foreign.
20 knots and over, ...	6	6
19 to 20 knots, ...	1	11
18 to 19 knots, ...	9	4
17 to 18 knots, ...	22	18
16 to 17 knots, ...	17	18
	55	57

It is an ominous fact that in the last eight years we have added only one oceangoing 18-knot ship to our Navy, while Germany has built four in the last four years. It is another ominous fact that, while we equal the combined merchant navies of the world in aggregate tonnage, of the 157 ships of 16 knots and over less than one-half the number are under the British flag. If we ex-

amine the lists of mercantile auxiliaries of the several Powers, we find that France has 32 vessels, the latest additions, the *Lorraine* and *Savoie*, having a displacement of over 11,000 tons. The speeds of the French subsidized steamers have been constantly increasing from the 15 knots of twenty years ago to the 17, 18 and 19 knots of modern types. The armaments provided for each ship include seven 5.5-inch guns and smaller quick-firers. In numbers the German auxiliaries do not compare with the French. There are, however, six ships of the first class, which, as it has already been observed, hold the record in the international competition on the North Atlantic. The armaments prepared for the German mercantile auxiliaries include eight 5-inch guns, four 4.7-inch, four smaller quick-firers and fourteen machine guns. The Russian fleet of auxiliary steamers consists of 25 vessels. In displacement each of these ships exceeds 10,000 tons, with speeds of 19½ to 20 knots. The British list of reserve merchant cruisers compares unfavorably with those of foreign Powers. It consists of 29 vessels, none being fitted with special protective arrangements.

With these comparisons before us, we must regret that so little heed should have been paid to the counsels of the able men to whom I referred in the opening of this paper; how little is attested by the fact that the amount payable to the owners of our reserve merchant cruisers under the naval estimates now before Parliament is £63,000 out of a total of £2,000,000 which Parliament is asked to vote for the Navy.

While we have taken no adequate measures to create a fleet of mercantile auxiliaries by the appropriation of moneys directly voted from Navy estimates, we have been sparing in our grants for postal services. The amounts paid have been computed by Mr. Henniker-Heaton, M. P., as follows:

Countries.	Money.	Total value of the foreign trade.
France, . .	£1,143,000	£300,000,000
Germany, . .	1,000,000	313,000,000
Russia, . .	251,000	111,000,000
Italy, . . .	400,000	182,000,000
Great Britain, .	637,000	750,000,000

The latest returns show no material changes in the figures given by Mr. Henniker-Heaton.

And now let us ask ourselves what steps it is practicable to take in furtherance of the policy which it has been the object of the present paper to recommend. And first, what is the proper sphere of action of the mercantile auxiliary? It was described by Lord George Hamilton in moving the Navy estimates for 1889. They would be employed in dogging the footsteps of a foreign rover and embarrassing a foe; they would act as the scouts of the fleet. The difficulty of keeping touch with a squadron has been strongly impressed in recent maneuvers. As scouts and patrol vessels, their long coal endurance would give to the mercantile auxiliaries an advantage over regularly-built vessels of war of even tonnage. Such being the *rôle* of the mercantile auxiliary, the qualities required are speed, coal endurance, internal subdivision up to Admiralty requirements, strength of hull. Guns must be carried at such a height above water as to be of service in a seaway. Lastly, there is the absolute requirement of protection from the shot and highly-explosive shell of quick-firing guns. The power of modern armaments to reduce unarmored superstructures to wreckage, to disable guns, and annihilate guns' crews has been signally shown in the battles of Manila and Santiago.

If the requirements were carefully considered in the original design, it would be possible to give as much, or nearly as much, protection to the mercantile auxiliary as to the regularly-built cruiser. Mr. Peskett, of the Cunard Company, has recently offered some practical suggestions on this subject in a lecture delivered at Liverpool. Mr. Peskett is a strong advocate for subsidies to mercantile auxiliaries, conditional upon the adaptation of the ships to the requirements of naval warfare. I may quote from a *précis* of his lecture.

"Merchant ships of the *Campania* or *Saxonia* class could actually be built lighter than they are under the present system if they were built with one very strong deck, such as a protective deck with sloping sides, or with a deck of cellular form. The disposition of material in some of our large steamers is not, per-

haps, in strict accordance with the best designs our naval architects could produce, but entirely due to the requirements of owners and the various registration societies. I should say that a cruiser's hull with protective deck is lighter in proportion to her displacement than that of many of our first-class passenger steamers.

"Taking into consideration the fact that our supremacy depends on the efficiency of our naval and mercantile marine, a committee of Admiralty officials, shipowners and shipbuilders should be formed to discuss the best method of constructing a combined naval and mercantile marine, and to consider whether ships could be built as merchant cruisers, with protective decks, ram stems, machinery and steering gear below the water line, and still be able to carry enough passengers and mails, which, with a reasonable subsidy, would make the ships remunerative to owners.

"These ships would have to be permanently mounted with light guns, racer plates for heavier armaments being built in the ships during construction, the heavier guns and mountings being kept at ports of call, and made to suit the various ships of any particular fleet."

It has always been recognized that mercantile auxiliaries cannot be effective unless specially designed for conversion into cruisers. In the discussion at the Institution of Naval Architects on Mr. Barnaby's paper, already referred to, Sir Edward Reed proposed that shipowners about to build large and swift merchant vessels should be invited to submit their plans to the Admiralty. The cost of any alterations which they might be willing to make in order to adapt these vessels for the emergency of war service should be met by a grant from the Government.

It is the main object of the present paper to urge the adoption of valuable and practical recommendations, which have been too long neglected. It is the fixed resolve of the people, and perhaps the first duty of British statesmen, to keep the Empire secure from attack, and to give protection to the commerce on which our existence depends. In pursuance of this policy we have more than doubled the expenditure under navy estimates, and

still we seem to fall short of the full requirements for the naval defence of the Empire. It would be impossible to fix a limit to the number of cruisers required for the protection of a commerce which extends over every sea. The construction of cruisers has absorbed in recent years a large proportion of the shipbuilding votes. But when the cost of the first-class types falls little short of that of the battleship, the numbers we can build are all too few for the work they might be required to do. We cannot cut down the expenditure on battleships.

If, therefore, our regularly-built cruisers are fewer than we could wish, we must look to our own mercantile marine, and, out of the abundant materials we there find ready to our hands, we may organize a supplemental fleet of armed cruisers such as no other State can furnish. The Admiralty should utilize these resources by liberal subsidies. The standard of requirements should be high. The speed should not be less than that of the *Deutschland*—let us say, 22 knots at sea. Mercantile auxiliaries should be protected by a deck or belt of Harveyized armor—the necessary armaments should be in readiness. Calculations of cost can hardly be attempted in a paper in which nothing more is attempted beyond suggesting a policy. This, at least, is certain, that the cost of the adaptations and protective arragements necessary in a mercantile auxiliary will be small in comparison with the first cost of a regularly-built vessel of war. For a first-class cruiser we may take the cost at three-quarters of a million. Allowing $3\frac{1}{2}$ per cent. on the money invested, adding 6 per cent. for depreciation, and 1 per cent. for insurance, we have in round figures for the first cost an annual writing-down charge of £70,000 a year.

In addition, there is the cost of maintenance, which, whether in commission or in reserve, will certainly be considerable. Allowing for the protective arrangements of the mercantile auxiliary the liberal sum of £50,000, and a writing-down charge on this amount of 10 per cent., and taking 10s. per ton displacement for the annual retainer, we have, for a mercantile cruiser of 10,000 tons, an annual charge of £10,000. We must further take into view the economy resulting from the maintenance of

the mercantile auxiliary by the ship owners, as against the maintenance of the man-of-war in our Royal yards. In conclusion, I claim that it has been clearly shown that we can have many auxiliaries for the cost of one cruiser; and these auxiliaries may have effective protection. If not equal to the ship of war as combatants, they will be superior in coal endurance and probably in speed for long distances. They would be the scouts of our fighting squadrons. They would protect our commerce from interruption by the auxiliary vessels of a hostile Power.

While the building of cruisers for the Navy should be continued, the resources we possess in the marine, which our maritime enterprize has created in extent practically without limit, should not be neglected. Here, in Glasgow, I look for powerful support to a policy not now presented for the first time to the consideration of the Institution of Naval Architects. It has been advocated for many years by your ablest men, it is being steadily pursued, to their signal advantage, by every naval administration. We are lagging behind, how seriously, has been shown by the figures which I have quoted. If the expenditure on auxiliary cruisers were raised from £60,000 to £600,000 a year, in a few years we should be enabled to provide no ineffective protection for our vast trade.

CONVERSIONS AND RE-ARMAMENT OF SHIPS ON THE EFFECTIVE LIST.

[Paper read before the Institution of Naval Architects.]

By the Right Hon. Lord Brassey, K. C. B., D. C. L.

Giving expression to the national resolve that the Navy shall be strong enough to ensure the integrity of the Empire, Parliament has in recent years voted appropriations for the construction of new ships with no unstinting hand. Fully approving the vigorous policy which has been pursued, I desire in the present paper to urge, as I trust with the unanimous approval of the Institution of Naval Architects, that we should use, to a larger extent than heretofore, the means we possess of reinforcing the Navy by conversion and repair. In a period of extraordinary developments in the manufacture of guns and armor, many sound and seaworthy ships require improvements to keep them up to date.

Such conversions should be rapidly proceeded with when once decided upon. The cost of conversion of the *Dreadnought* was £99,531, but it is highly probable that the expenditure was so large mainly because the work was spread over the five years, 1895–1900. The Admiralty has so much administrative work that a consultative committee might be useful in advising as to reconstruction and repair. Such a body might afford the Committee of Public Accounts the information desired in its report, dated May 15th, 1901, where it says that, "before determining upon the policy of the refit and repair of an old ship, a very careful estimate (all the more careful because necessarily only approximate) of the probable total cost should be made and considered by the Admiralty, and should be presented to Parliament at the earliest opportunity."

The policy I desire to recommend for the British Navy has been actively pursued by foreign Powers. I might refer to the conversion of ships belonging to the Austrian Navy; to the rebuilding of monitors in the United States and, more particularly, to the extensive work of reconstruction which is in progress under the French Naval Administration. In France, as the result of an exhaustive examination of the subject, a scheme was approved in 1896 for the reconstruction of five coast-defence vessels. In 1897 a similar scheme of reconstruction was approved for no less than ten battleships.

The alterations which have been carried out include the cutting down of the heavy superstructures with which the French ships of the most recent types have been encumbered; the fitting of Belleville and Niclausse boilers; the modernization of machinery, and the arming of the ships with guns reduced in caliber and lighter in weight, but having a more commanding range than the earlier patterns.

An enumeration of the ships with which it was decided to deal will probably be received with interest. The ten battleships include the *Formidable*, *Baudin*, *Courbet*, *Redoutable*, *Devastation*, *Hoche*, *Marceau*, *Amiral Duperré*, *Neptune* and *Magenta*. The oldest ship in this list is the *Courbet*, launched in 1881; the latest is the *Magenta*, launched in 1890. The ships already converted are the *Formidable*, *Courbet*, *Redoutable*, *Devastation* and *Marceau*. The list of coast defenders includes the *Terrible*, launched in 1881; the *Caiman* and *Indomptable*, both launched in 1885. These three ships are actually in hand. To complete the list, we have the *Requin*, launched in 1885, and partially rebuilt in 1896; and the *Furieux*, launched in 1883.

The refit of the *Amiral Duperré* includes new boilers and the substitution of four 6.4 quick-firing guns in a central casemate for the 13.3 gun formerly carried in the barbette amidships. The refit of the *Neptune* comprises the substitution of Bellevilles for cylindrical boilers, and the necessary adaptations of engines for working at higher pressures. The ponderous superstructure will be removed.

In the coast-defence ships the work of reconstruction has been

carried further than in the battleships. In the *Requin*, of 7,800 tons, and built fifteen years ago, the armor of the belt has been reduced from 19.5 to 9 inches. For the 16.5 guns formerly carried, two 10.8-inch guns have been substituted. Lightened to the extent of over 600 tons, the ship will be more seaworthy and better protected. The expense has been estimated at £80,000—it is only an estimate. The *Furieux* is to be fitted with Belleville boilers. Two 9.4-inch guns in closed turrets will be substituted for the two 13.3-inch guns formerly mounted in the barbettes. The ship will be lightened by 246 tons.

The total expenditure originally authorized for the refits and reconstruction recently undertaken in the French Navy was, in round figures, a million sterling. It goes without saying that this figure may be considerably exceeded. If we add £500,000 to the first estimate, the expenditure will be amply justified. No less than fifteen ships, which were becoming obsolete in armaments, armor, boilers and machinery, will have been brought up to date. A policy pursued with such successful results in France should be good for our own Navy.

A member of Lord Northbrook's administration naturally looks to the ships of that period. Would that we could pronounce them as perfect by the light of recent developments as we thought them at the date when they were projected. Our six ships of the *Admiral* class were highly commended by competent critics. They steam well, and carry a fair coal supply. They are powerfully armed, and afford steady gun platforms. In other features they are less satisfactory. Since the *Admiral* class were designed, now nearly twenty years ago, we have seen a striking advance in the power of attack by quick-firing guns, and in the power of resistance by armor. Modern armor is equal to twice its thickness in the compound armor of the *Admiral* class, while modern guns have greater range and rapidity of fire and flatter trajectories. The total want of protection for the secondary armament of the *Admiral* class, always a weak point, has become a more grave fault, in view of the increased power of attack on an unarmored battery by quick-firing guns firing high explosives. The *Admiral* class would gain greatly in fighting

efficiency if their batteries were protected. To give protection to the batteries, weight must be saved in other parts of the ship. In the barbettes two pairs of 28-ton guns might be substituted for the 12-inch guns at present mounted. The compound armor on the barbettes should be replaced by a more modern type of less thickness. Ships of the *Admiral* type, with the improvements which might be introduced, would be a match for many vessels which will long be retained on the lists of foreign Powers.

Pursuing a similar policy, the belted cruisers of the same period should be taken in hand. The programme recommended to Parliament by Lord Northbrook included seven ships of the *Aurora* type of 5,600 tons. They are powerfully armed. They have a measured-mile speed of 18 knots, and a coal endurance of 8,000 miles at 10 knots. Within the limits of displacement available, it is simple justice to Sir Nathaniel Barnaby to say that the highest combination of qualities was obtained. By a liberal expenditure, judiciously applied, the *Aurora* class might be brought up to such a standard of fighting efficiency as would keep them on the list of "effectives" for many years. The improvements urgently required are increase of length, more freeboard forward, and greater protection by armor on the sides amidships. The necessity for increased length is clearly seen, when we look to the French types of approximately similar dimensions. Our belted cruisers, with a displacement of 5,600 tons, have a length of 300 feet. The French cruisers, both armored and protected, have a conspicuous advantage in length. As examples, we may quote *Amiral Charner* and two sister ships, displacement, 4,792 tons, length, 348 feet; *Pothuau*, displacement, 5,360 tons, length, 370 feet; *Dupuy de Lôme*, displacement, 6,406 tons, length, 374 feet; *Catinat* and two sister ships, displacement, 4,065 tons, length, 330 feet; *Jean Bart* and two sister vessels, displacement, 4,100 tons, lengths varying in the different designs from 326 feet to 346 feet; *Cécille*, displacement, 5,933 tons, length, 378 feet. The lengthening of the belted cruisers would render many improvements possible. A large area of side might be protected, as, in the case of the French

Dupuy de Lôme, with modern armor. Higher speed would be obtained with the same horsepower. The coal supply would be more ample. The bow might be raised—an important advantage in steaming against a head sea.

Having indicated a general idea, a non-professional administrator must leave the practical application to constructors and shipbuilders. In the case of ships built by contract, the work of conversion might be done by the firms that constructed the ships. As Sir James Williamson, the Director of Dockyards, recently said, "The day is coming when the Admiralty must look to private firms to do repair work for the Navy, and I do not think they could do better than bring the ships back to the firms who built them." Allowing a wide margin, an expenditure not exceeding that of a single battleship should effect immense improvements in the six ships of the *Admiral* type. An expenditure not exceeding the cost of a first-class cruiser should give us seven converted armored cruisers which for many years would be capable of rendering effective service.

Expenditure on re-armaments and on the fitting of new machinery for the older types of battleships is not viewed with favor by contractors and shipbuilders. It must always be a more grateful task to build from original designs, the creation of their own science and invention, rather than to modernize ships which are becoming obsolete. Within prudent limits, no expenditure would yield more immediate results. The time taken for conversion need not exceed one-fourth that required to build a new ship. In war with a first-class Power, the sphere of action of our converted ships would be found in distant waters, and it is important that our flag should be carried worthily. The newest ships would be found in squadrons near home in the Mediterranean and the Channel.

As has already been shown, the French are wisely making liberal appropriations for reconstructions, conversions and refits. We throw away resources we possess ready to our hand if we delay to follow on the same lines.

Discussion.

The discussion on the two papers by Lord Brassey was combined, and the following synopsis of it is from "Engineering."

Admiral Sir E. R. Fremantle was the first speaker. He commenced the discussion by saying that Lord Brassey had given very good reasons in his paper why mercantile cruisers should be considered invaluable to this country. In a recent discussion Commander Clover, of the United States Navy, had said that the large merchant vessels had proved most useful auxiliaries in the late war between Spain and the United States. Sir Edmund Fremantle was, however, of opinion that these large ocean liners should not be used so much as tramps, but rather to be sent to distant parts of the world on long voyages carrying information. The gallant Admiral gave at some length, in support of his contention, historical instances in which the value of fast vessels had been proved in actual warfare. We have now, he said, on our list 140 cruisers of various sorts; a larger number was undoubtedly necessary but he agreed that it was impossible to increase the number of war cruisers so as to bring them up to what would be required to protect our now vast mercantile marine in case of war. Conditions were changed since the old days; then the area of warlike operations on the sea was covered by the Mediterranean and the Atlantic; now we have the eastern seas of Asia, and, indeed, the oceans of almost all the world. Turning to another aspect of the question, Admiral Fremantle said that a mercantile marine is absolutely necessary as the nursery of a powerful navy. A fleet thus unsupported would be an exotic, and would only last a limited period. He agreed with the author that subsidies should be liberal; £600,000 had been mentioned. That might seem a large sum, but, after all, it was less than the cost of a first-class cruiser of modern days; indeed, little more than that of a second-class cruiser. In considering the problem of conversion of mercantile vessels to warlike purposes, armored protection was undoubtedly the serious difficulty. He did not see how protection could be given to machinery as now fitted. In addition

to the main engines there were other features, such as the steering gear, which is placed on the upper deck; indeed, sometimes the steering engine was placed there too. Irrespective of these points, there would be no difficulty in making use of merchant vessels. Protection of men at the guns had been alluded to, and was no doubt important; but it was protection of machinery that had to be considered if merchant vessels were to be in a position to meet even the smallest cruisers. In regard to the paper on conversion and re-armament, he held that if such a system were to be carried out, it must be done in a thorough and complete manner, and on a well-defined system. Some time ago Lord Charles Beresford had read a paper, in which he advocated putting breech-loading guns in place of muzzle-loading guns in some of the older vessels of the fleet. Admiral Fremantle opposed this suggestion, for the ships themselves were not suitable for warlike purposes in other respects. The case, however, was different with the more modern ships to which Lord Brassey alluded, and here the speaker expressed a different opinion. He gave an instance of the foolishness of piecemeal alterations in the case of the *Témeraire*, the alteration of which ship afforded an example of how "not" to do it. She had had her old-fashioned secondary armament taken out, and more modern quick-firing guns put in; then the masts and yards had to be removed to fall in with the new arrangement; that necessitated the installation of a derrick for lifting boats in and out; then the bridge had to be removed, and other changes made. These haphazard alterations involved great outlay, and yet the ship was no good. Another instance given, was that in which an effort had been made to bring a ship up to date by the substitution of more modern boilers, and here again there had been failure owing to the other features not being in keeping. The *Admiral* class had been referred to by the author, and in many respects they afforded excellent material for conversion. The armor might be re-distributed, the guns replaced, and protection might be given to the secondary battery at a cost, he estimated, of £200,000, and the result would be worth the outlay. The *Orlando* class might likewise be improved. These vessels would

be better for being lengthened, and this operation, together with other necessary alterations, could probably be carried out for £100,000. He would like, in conclusion, to say one word about coast-defence vessels; although he trusted our own coasts would never need any immediate defence, yet we might have to attack the coast line of our enemies. On the principle that a cat getting into a window is very much like a cat getting out, he thought that coast-defence vessels would make the best coast-attack ships.

Sir Nathaniel Barnaby was the next speaker. He regretted the absence of the Director of Naval Construction, Sir William White, who would have given the meeting the benefit of his ripe, wise and sound judgment. Referring to what had been said about the *Admiral* class, he thought that justice had not been done to these vessels. It had been said that there was no protection to the secondary armament; that, however, was not true, as there were armored bulkheads standing right across the ship. He thought that if alterations were made, it would be possible to arrange the weights so as to bring the secondary armament quite within the battery. He fully agreed with what Lord Brassey said on the question of auxiliary armaments. In the paper reference had been made to the part he, the speaker, had taken in former times in the discussions on this subject; but Lord Brassey had omitted to state that before he, the speaker, had read his former paper at a meeting of the Institution of Naval Architects, Lord Brassey had mentioned the subject to him in conversation. From the point of view of members of the Institution, the adoption of auxiliary cruisers on a larger scale was eminently desirable. Naturally, the contractors wanted to build the ships; but there was more than that, for the Institution wished the country to be provided with the best means of defence for its commerce and interests. It was unreasonable to expect private builders and owners to inaugurate changes which would make mercantile vessels efficient ships of war. If this were to be done, the country would have to provide the money. There was one point to which the attention of the meeting might profitably be called in regard to the conversion and re-armament of ships. Battleships did not

become obsolete in the same way as cruisers. The latter were designed expressly for speed, and the progress of engineering science was always making higher speeds possible. In battleships it was not speed that was the paramount quality; and he considered these vessels did not deteriorate more rapidly than at the rate of 2½ per cent. per annum. In mercantile auxiliaries, however, the ship would not become entirely useless because a greater speed had been made possible; for though she might be outclassed as a cruiser, the private owner would not throw her out because she was not quite as fast as some other vessel. The German members of the Institution, whom everyone would be pleased to see present in such numbers, Sir Nathaniel continued, would be glad to hear that so high an English authority as Lord Brassey considered they were proceeding on right lines in building these large ocean liners of high speed, which might form a notable addition to their Navy. If, said the speaker in conclusion, Lord Brassey's views as expressed in the paper are carried out, a greater step will be taken in this direction than any which marked the century that has just closed.

Professor J. H. Biles, who spoke next, said that many might ask why such a question as that put forward by the author on mercantile auxiliaries should be brought before the Institution. It was a political question, in the main, dealing with the naval policy of the Government. It was also a question dealing with the economic side of Imperial Defence. Was it desirable to spend more money on mercantile auxiliaries and less on the Navy, or *vice versâ?* But in whatever place the subject were brought up, it must ultimately be referred to the Institution, or to some of its members, to answer the question—Whether a mercantile ship can be designed so as be to capable of being converted into a formidable warship; and, if so, at what cost and sacrifice of essentials? Seven years ago the speaker had read a paper before the Institution and had dealt with this side of the subject in considerable detail. The figures therein given remained to that day unchallenged by any responsible person that he knew of. It might therefore be of service in dis-

cussing the paper if he briefly stated that the conclusion then arrived at, Can our mercantile steamers be made available for war purposes? was the question. Lord Brassey entitled his paper "Mercantile Auxiliaries," but apparently he intended the mercantile vessels to act as auxiliary cruisers, scouts, &c. In the speaker's 1894 paper he endeavored to show how a first-class mail steamer could be adapted in her original design so that she could in war times be made for gun, torpedo and protective capabilities little, if any, inferior to our first-class cruisers, while in speed and coal endurance she would be superior. He dealt with a ship of the size of the *Etruria*, and showed that in her case by appropriating 600 tons, or 4 per cent. of her total displacement, to permanent weights which would have to be carried in peace time, and by putting on 2,600 tons, or 18 per cent. of her displacement, in war time, she could be armed, protected and provisioned as a first-class cruiser. The permanent loss of deadweight cargo carrying must be paid for by the State in some form. Either the authorities could insist that vessels should not carry passengers unless they were capable in some form of contributing to the defence of the country; or, in the other extreme, they might pay the owners for the additional first cost and loss of revenue. But this loss of carrying was not so great as it appeared to be. If the vessel had capacity for cargo, it only meant that she would load perhaps a foot deeper, and would require more coal to propel her; it was capacity generally in high-speed steamers that limited cargo carrying, and not dead weight. This adaptation of such a ship to war purposes would be paid for by an annual expenditure of £19,000 to the shipowner, and a first cost of £220,000 for armor and guns, which would have to be provided in any case, whether the ship were a regular naval ship or merely a useful mail steamer.

What could really be made use of in peace times was the hull and machinery of the ship, the armor and guns being left in store. In war time the ship would put on her armor, take her guns on board, and, with the muscles and sinews well trained in peace, stalk forth a man-of-war in search of her country's foes. She represented the most modern idea of the soldier—the useful,

hard-working citizen in time of peace, who, when the war time comes, goes forth to fight with as good spirit as the professional soldier, and not infrequently with as great and glorious a result. The question Lord Brassey had put—and he had put it many years ago, before the Boer war had shown what our citizen soldiers can do—was whether the resources of our non-fighting fleet had been sufficiently considered in our scheme of national defence? Had our mercantile auxiliaries been starved as our volunteers had been? And would it be necessary to have a disaster on the sea to bring home to our so-called statesmen the value of our citizenship? Should we be told then that more was known about the value of mercantile auxiliaries than by the man in the street? He thought the Institution—not a man in the street on this subject—would be well advised if it took such action as would support Lord Brassey in his endeavor to awaken the authorities to a full sense of the value of mercantile auxiliaries, and if owners were encouraged to design their ships to be of real fighting use in war time.

Admiral Sir N. Bowden-Smith was the next speaker. He said it was for naval architects to decide how far mercantile vessels can be altered so as to be made available for warlike purposes. Professor Biles had given his views in a very clear and concise manner. When Lord Brassey was reading his paper, the figures which he gave respecting our own and foreign merchant vessels produced a most unpleasant effect on the speaker, and it seemed we were in by no means the position we formerly held. On consideration, however, he found some reason for hope; for though inferior in speed in the larger class of ships, we had numbers such as no other country possessed. During the last two years the English marine had performed a feat which could hardly have been accomplished by any other country in the world within the same period of time. They had been able to transport a quarter of a million of soldiers with their horses, forage, stores, &c., to South Africa, and that all had been done under the British flag. In dealing with this question of mercantile auxiliaries he thought it wise to consider what a

naval officer would do in the case of war if he had such vessels under his command. The problem had been brought home to him when he was Commander-in-Chief on the Australian station. On that occasion we had one of our numerous war scares, and someone had asked him what he would do with mercantile cruisers in case of hostilities being commenced. He had replied that he would do his best to keep these vessels on their ordinary routes unless some immediate use were to arise for them. The great advantage to this country in the case of war, would be to keep the shipping running as at other times, and to do this it was well that the vessels should be armed, as they never could be sure when they would meet with cruisers of the hostile country. How far the risk of battle should be taken, to what extent the lives of passengers should be jeopardized, was a matter that must be decided by the captain of the vessel. The gallant Admiral referred to the suggestion contained in the paper of the formation of a committee to consider this matter. He pointed out the extent to which the Naval Lords of the Admiralty were absorbed in their duty. He had known several First Sea Lords of the Admiralty go into office, and after that they were never seen out of their rooms at Whitehall. This was evidently due to the extent to which they were absorbed in office duties.

Dr. Francis Elgar said that this question of mercantile auxiliaries was one of money. He agreed with Professor Biles that there was no difficulty in so designing mercantile vessels of the largest class as to make it possible to render them as effective as some cruisers. Protection was only a matter of cost. Lord Brassey had said that the shipbuilder should state how much the thing would cost, but Dr. Elgar was of opinion that no shipbuilder was in a position to give a reliable estimate. He would therefore urge that the Institution should strongly support the proposal contained in the paper that the question should be referred to a consultative board. He would suggest that such a board be composed of naval officers, Admiralty constructors and possibly private shipbuilders. In no other way than by the

labors of such a body could an answer be got as to the cost of proposed work of this nature. He fully agreed with Sir Nathaniel Barnaby that if the advice of the author were followed, and a committee were formed, good service would be done to the State. Although he could not state himself figures as to cost, he felt quite sure that Lord Brassey's money estimates were over-sanguine.

Admiral Sir J. Dalrymple Hay said that he would not take part in the discussion at large, as time was so extremely limited; but he would urge that the Institution should take some steps to put the proposal of the author in regard to the formation of a committee into practical and effective shape. He would, therefore, beg to move the following resolutions:

"That as our supremacy depends on the efficiency of our naval and mercantile marines, a committee of Admiralty officials, shipowners and shipbuilders should be formed to discuss the best method of constructing a combined naval and mercantile marine."

Dr. J. I. Thornycroft seconded this motion, which was subsequently put to the meeting and carried unanimously.

Admiral Sir John Hopkins had sent the following communication on Lord Brassey's papers to the secretary: "I hold strong views on both the conversions and re-armament of ships on the effective list, as also on the subject of mercantile auxiliaries. In regard to the first, I may mention that in a paper I read at the United Service Institution in December last I advocated, *inter alia*, the *Admiral* class being reconstructed unless replaced; but as the latter seems at present out of the question, I am strongly in favor of conversion. I am also strongly in favor of putting the work out to contract, as the Royal dockyards are too full of other work to attempt more at present. I may be pardoned for quoting from the paper I read formerly at the Royal United Institution a rather fuller extract than the one bearing on the conversion of the *Admiral* class, but as part of a reconstruction scheme I insert it:

"We may also hope early in the coming century to get rid of

all muzzle-loading guns by eliminating from the navy list all ships carrying them. By this measure the simplification of our ordnance and all its accessories would alone be an untold blessing, as then, roughly speaking, we should have only nine descriptions of heavy guns, whilst we should get rid of about a dozen kinds of obsolete weapons for which powder, projectiles, stores, &c., must be maintained, as also spare guns and spare mountings, not to mention the occupation of most valuable storehouse room by these obsolete weapons. There are two ways of carrying this out: one being to let time work out the change, as is apparently the present intention; the other to face the situation, ear-mark the ships to drop out, and commence the replacement at once. For the sake of illustration we will take at haphazard the following ships with muzzle-loading guns, none of which, by their peculiar construction, can mount an auxiliary armament of breech loaders. Some are practically useless amongst modern ironclads. The ships are:

"*Agamemnon*, *Ajax*, *Neptune*, *Superb*, *Témeraire* and *Inflexible*, whose united displacement is 56,620 tons. Working to this tonnage will give us four 14,000-ton ships, or five of 11,000. Let us assume we prefer the five, and construct them as improved *Barfleurs*, two of them to be started at once, two the following year, and one the year after, on a supplementary estimate, so as not to cut across the ordinary shipbuilding programme. Accepting the time for construction as three years, we have *Témeraire* and *Neptune* dropping out in 1903, *Superb* and *Inflexible* in 1904, and *Ajax* and *Agamemnon* in 1905, with the remainder to be dealt with then on similar lines.

"Let us also face the replacement of cruisers, or eliminate at once from the navy list all obsolete first-class cruisers of the *Nelson* type, as also any other now-called first-class cruisers, such as *Agincourt*, *Northumberland* and *Minotaur*.

"Then early in the next century may we not look forward to the *Admiral* class being replaced, or, failing that, reconstructed with a view of so reducing present weights as to provide plating or casemates for their 6-inch auxiliary armament? And I cannot help thinking that with their present 18-inch belt reduced to 6

inches, as in the *Glory*, their heavy barbette guns changed to 10-inch guns as in the *Renown*, and other weights carefully cut down, the alteration can be effected.

"Let us also contemplate the change of guns from muzzle to breechloaders in such ships as the *Monarch* and *Dreadnought*, if still retained on the effective list.

"In respect to the other questions of 'Mercantile Auxiliaries,' I am entirely in accord with Lord Brassey's views, and can urge nothing stronger or more to the point than his paper presents; in fact, I may say that both papers represent strongly the views of many naval officers, and if acted upon by the authorities, cannot fail to increase our fighting strength afloat in a marked degree."

The President next called on **Lord Brassey** to reply to this discussion. His lordship said that though there was much that might be discussed, the time of the meeting was so short that he would simply content himself with thanking the members present for the way in which his papers had been received and the discussions to which they had given rise.

THE GROUNDING OF THE GERMAN BATTLESHIP *KAISER FRIEDRICH III.*

[Translated from "Marine Rundschau."]

The damage to the *Kaiser Friedrich III*, following her grounding on the 2d of April, 1901, north of the Adler Grund, is the greatest that any of our modern ships have ever sustained, and for that reason, and on account of the attending circumstances, commands general interest.

On the return from Dantzig to Kiel, the vessels of the first squadron were detached at 11 A. M. April 1st for the purpose of undertaking their 3-hour forced-draft and 24-hour endurance trials. The *Kaiser Friedrich III* had easily maintained her horsepower on the 3-hour trial, and had exceeded her trial speed. On the endurance trial that followed, she made nearly 16 knots, and was making a course by soundings and by bearings for the Adler Grund lightship, the least depth on the course being 13 meters, and distant one-half mile from the lightship, at which the depth is 9.5 meters. The weather was clear and bright, the moon was shining and the sea smooth, and the wind W.S.W., force 2.

At 1·23 A. M. the lightship was passed to port at a distance of from 550 to 600 meters. Soon afterwards, at 1·27, the captain and the officers who were on the upper bridge, experienced a sensation as if the engines were suddenly reversed, or, at least, had their speed materially altered, while the chief-of-staff, in the after part of the ship, observed a clattering noise.

Before commencing the run, the ship was drawing 7.9 meters forward and 8.2 aft, but on account of her high speed she was squatting about one-half meter. To the circumstance that the rocks on which she lay were at a depth nearly equal to the ship's draught, as well as to the high speed of the ship when she struck, may be ascribed the fact that the damage was not greater.

The captain immediately communicated by speaking tube with the center engine room and inquired the cause of the disturbance, receiving prompt reply, "Leak in compartment 6, port after boiler room." He at once gave orders to close watertight doors, and then started the engines ahead slow. The alarms as well as the transmitters worked very well, and, despite the darkness, the collision stations were manned in the shortest possible time, so that in a few minutes the captain was able to report to the squadron commander, acquainting him with the nature of the accident and the precautions that had been taken. A proof of the efficiency of the crew at collision quarters is to be found in the fact that the survey held in dock confirmed the reports received from the principal stations at the time of the accident. According to these reports, water was rising rapidly in the port after fire room (compartment 6), and the fire room would have to be abandoned; there were leaks through the double bottom, on the port side in compartments 5, 6, 7 and 8 (frames 32 to 57), and on the starboard side in compartments 6, 7, 8, 9 and 10 (frames 40 to 78); compartments 11 and 12 were full to the platform deck; water was entering the ventilating engine room (compartment 10); and in compartment 1, the stern frame was broken near the hull, so that only a careful use of the rudder was permissible, and water in small quantity was entering there.

The squadron commander had in the meanwhile signaled the *Kaiser Wilhelm II*, which was near, to discontinue her trial and to stand by the flagship, and himself personally looked into the extent of the injury and the precautions that had been taken.

While the work of trying to stop the leaks was proceeding, fire broke out in the starboard middle fire room (compartment 8), from the escape into it of tar oil, so that the engines had to be stopped and the magazines in compartments 7 and 9 flooded. The boats, which had been made ready, were now lowered by order of the squadron commander, and, in obedience to signals, the *Kaiser Wilhelm II* also lowered hers and sent them alongside.

On account of the extinguishing of the electric lights and the uselessness of the speaking tubes to the engine and fire rooms, further complications arose; but after some time the fire was

put out by pouring water down the ventilating hatches, so that towards 4 o'clock in the morning the boats were hoisted and the ship taken in tow by the *Kaiser Wilhelm II.*

While this work was going on, the squadron commander sent a steam launch to Sasniz with dispatches; it returned at 11·30 A. M.

In towing her, the hawser broke, and on this account, after making a thorough examination of the steam pipes, steam was raised in the uninjured forward boilers of the *Kaiser Friedrich III*, the wing engines started, and the return to Kiel begun at a speed of 5 knots. The center engine remained inoperative, and was not used until later, in order that too much strain might not be put upon the broken stern frame. For the same reason the rudder was not put over more than five degrees when using the wing engines. Besides, the ship steered much worse than formerly, on account of her great draught forward and the injury to some of her screw blades, and showed a strong tendency to come up into the wind. Even with two steamers alongside, which, with the *Baden*, *Württemberg* and *Sachsen*, had been sent from Kiel to her assistance, it was impossible to steer any better; so the steamers were cast off, and by moderate use of the center screw and rudder the trip to Kiel was continued.

At 11 P. M., April 2, the coal in the bunkers alongside the forward and middle boilers (compartments 8 and 9) commenced to smoulder, but in each case it was possible to reach the burning portion, and so danger from this source was avoided. Thus was the trip completed without serious difficulty, and at 11·25 on the morning of April 3 the ship made fast to buoy No. 5 at Kiel. There, by discharging the magazines and pumping out the boiler rooms, after temporarily stopping the leaks in compartment 6 with collision mats and sails, she was lightened sufficiently to go into dock on the 11th.

EXTENT AND NATURE OF THE INJURY.

The ship first struck forward of frame 83, and amidships. From frame 83 to 74, the keelplate was indented for a depth of 8 inches and broken at frame 80. The outer skin between these frames was torn, and water entered through several leaky rivets

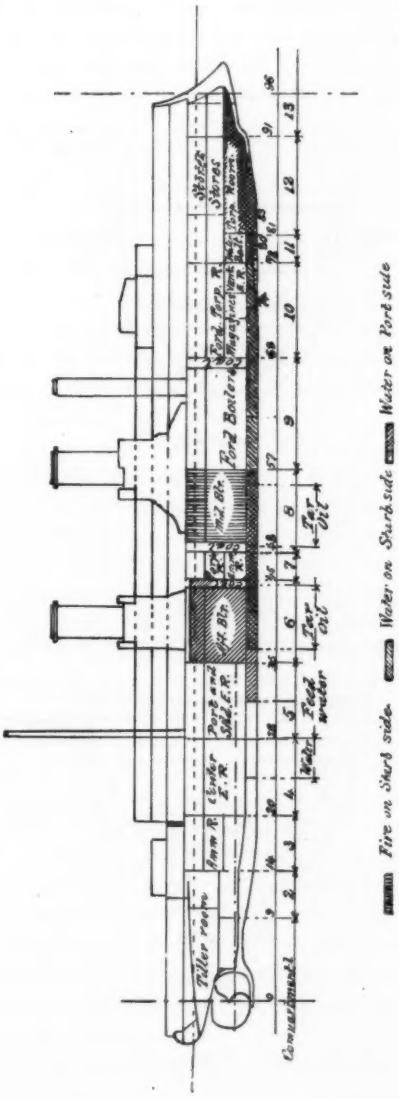

Stores
Fwd. Fire R.
Fwd. Boilers
Aft. Bkr.
Aft. Bkr.
Fwd. and Mid. L.R.
Upper L.R.
Fwd. Fire R.
Fwd. Engine Room
Fwd. Dist.
Aft. Dist.
Fwd. water
Aft. water
Fire on Stard side
Water on Stard side
Water on Port side

Fig. 1

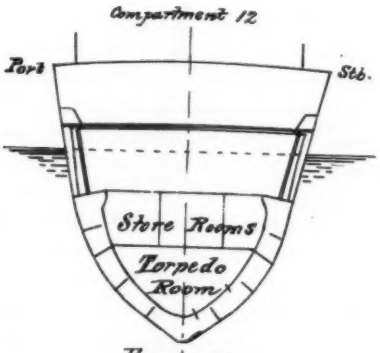

Compartment 12
Port
Stb.
Store Rooms
Torpedo Room
Frame 83.

Fig. 2.

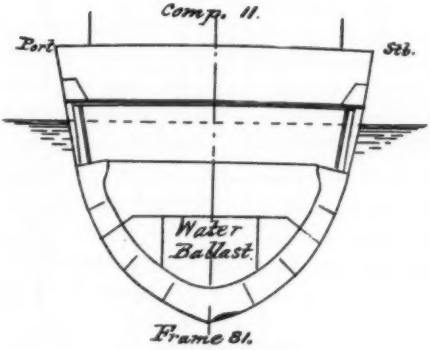

Comp. 11.
Port
Stb.
Water Ballast
Frame 81.

Fig. 3.

and seams in the inner skin of compartment 12; in addition, there was in this compartment a very leaky manhole cover that was bent on one side and permitted that compartment to fill.

Further, on the starboard side, a rock tore open four plates of the outer skin at frame 72, near the 2d longitudinal. This longitudinal itself was broken, and the first row of plates, from frames 68 to 34, slightly bent, but without any leakage of consequence.

The inner skin in compartments 9, 8 and 7 was bent in several places by reason of the pressure due to the bending of the frames, but no leakage occurred here.

On the port side, the first row of plates of the outer skin, from frames 57 to 32, was bent in and had several holes in it, apparently made by the same rock that the keel plate struck. In compartment 8, the body of the main drain valve was broken by a blow from below.

The shoe of the stern frame was shoved upward and broken off about ¾ meter below the joint. The rudder was bent slightly, and the stern frame cracked through on the forward side of the frame. Through this rent water filled compartment 1. The screw blades were more or less bent and broken.

In the starboard middle fire room (compartment 8), the ventilating pipe for the oil fuel tanks in the double bottom was broken in two places. The escaping oil ignited at the front of the boilers, and, on account of the great heat thus caused between decks, the boiler uptakes and the blower ducts were buckled and some of the armor-deck beams cracked. Besides, in the fire room itself, the electric-light cables, the mountings of both cylindrical boilers, the auxiliary engines and the piping were injured. Thanks to the precautions taken by the engineer force, the boilers themselves have not suffered, so far as the examinations made and the water-test pressure disclose. In the port after fire room (compartment 6), which was filled with water, on account of the injury to the body of the main drain valve, the damage was much less serious. The boilers and their mountings are uninjured, and only the piping and the boiler clothing need thorough examination.

On account of the injury, the double bottom subdivisions of

compartments 11 and 12 filled on both sides; then, on the starboard side, all subdivisions of compartments 10 to 6, from frame

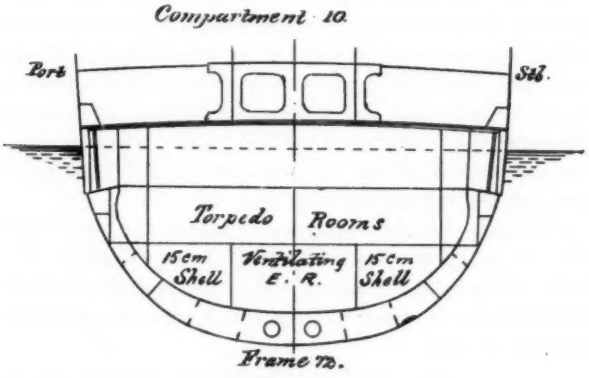


Fig. 4.

78 to 40, and, on the port side, those of compartments 8 to 5, from frame 57 to 32. All these compartments hold 738 tons.

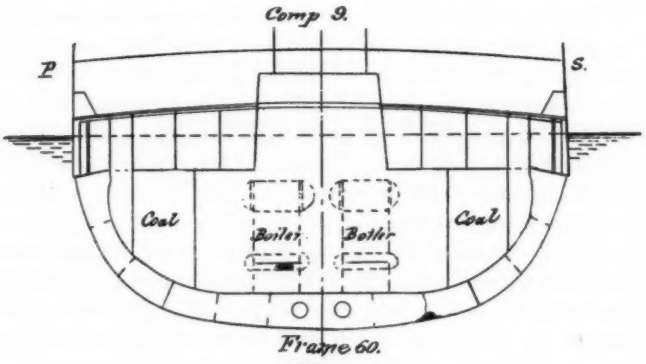


Fig. 5

(There were about 300 tons of tar oil and water in these compartments before the accident.)

Above the double bottom water entered as follows:

In compartment 12 (torpedo room), through a leaky manhole cover and leaks in the inner skin, to the height of the 'tween decks.

In compartment 11, through small leaks in the trimming tanks, to the height of the platform deck.

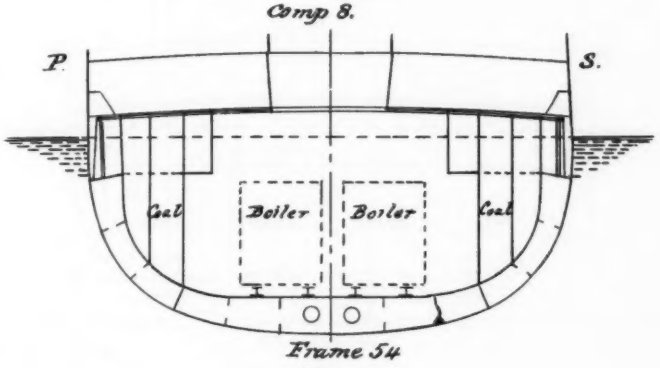


Fig. 6

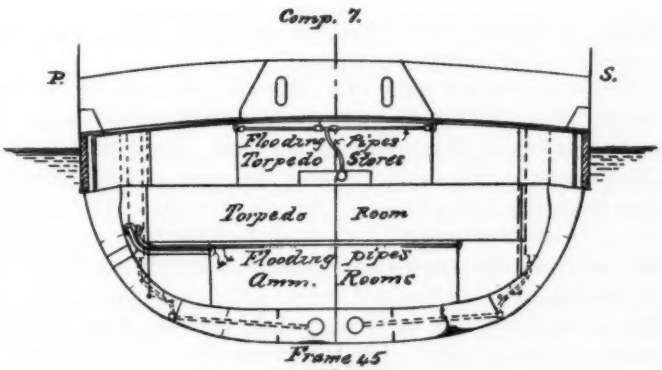


Fig. 7.

In compartment 10, in the ventilating engine room, through the pipes connected with the automatic non-return valves, one of the three valves not closing tightly, the design being such that

they close by pressure from outboard, although at the test of these valves made on the 23d of March this one did work well. The water came in from the overflowed portion of compartment

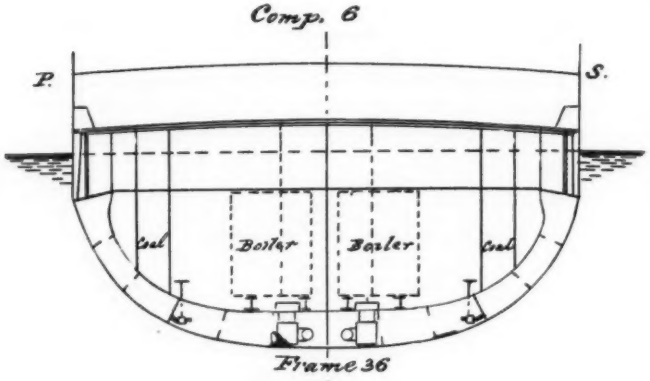


Fig. 8

11, and also forced its way from the ventilating engine room into a portion of the ventilating system.

In compartment 6 (port after fire room), through the broken bottom of the automatic main drain valve, between frames 36 and 37, and thus directly into the fire room. The bottom of this valve casing is only $4\frac{1}{2}$ inches from the outer skin. The water rose so rapidly in the fire room that the men on watch had time only to close the bunker doors, to shut off the boilers and raise the safety valves before the fires were extinguished, the water meanwhile rising above their knees. The water rose rapidly in the passageways, and, on account of the doors in these passageways not closing tightly, into the 'tween decks of this compartment. (These doors were designed to close tight by pressure from without.) Finally water entered the longitudinal and athwartship bunkers and filled them completely, probably on account of small pieces of coal jamming between the door and the bottom of the frame.

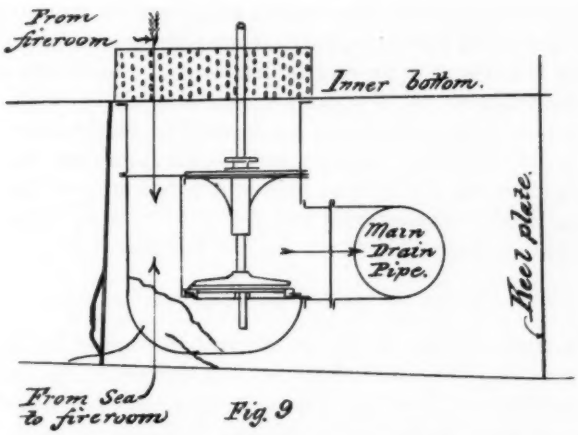


Fig. 9

Compartment 1 was filled by water entering around the broken stern frame.

The total quantity of water that entered the ship was about 1,200 tons. It increased the draught forward to over 9 meters and aft to nearly 8.5 meters, besides giving the ship a list to port, which, with the slow filling of the longitudinal and athwartship bunkers, finally exceeded 4 degrees.

EXTINGUISHING OF A PART OF THE ELECTRIC LIGHT.

About 45 minutes after the flooding of compartment 6 the entire electric lighting of the engine and fire rooms was put out by short-circuiting, so that work had to be carried on by emergency lights.

FAILURE OF SPEAKING TUBES.

When compartment 6 was flooded, all the speaking tubes passing through this compartment to the forward fire room failed on account of filling with water, and thereafter orders had to be transmitted by messenger.

EFFECT ON THE WORKING OF THE ENGINES.

The main and auxiliary steam pipes passed through compartment 6, which was full of water, but the fear that it would not

be possible to use the bilge pumps on account of the condensation that would take place in the steam pipes proved groundless. Steam from the port forward boilers could be used with safety for the engines. At first the pressure dropped as much as 20 or 30 pounds, and there was much water of condensation in it, but it did not cause water hammer. Towards the end, this condition improved, and after 24 hours the temperature of the water in the flooded compartment was about 122 degrees Fahrenheit, and after 50 hours, 165 to 170 degrees Fahrenheit.

ESCAPE OF TAR OIL INTO THE FIRE ROOM.

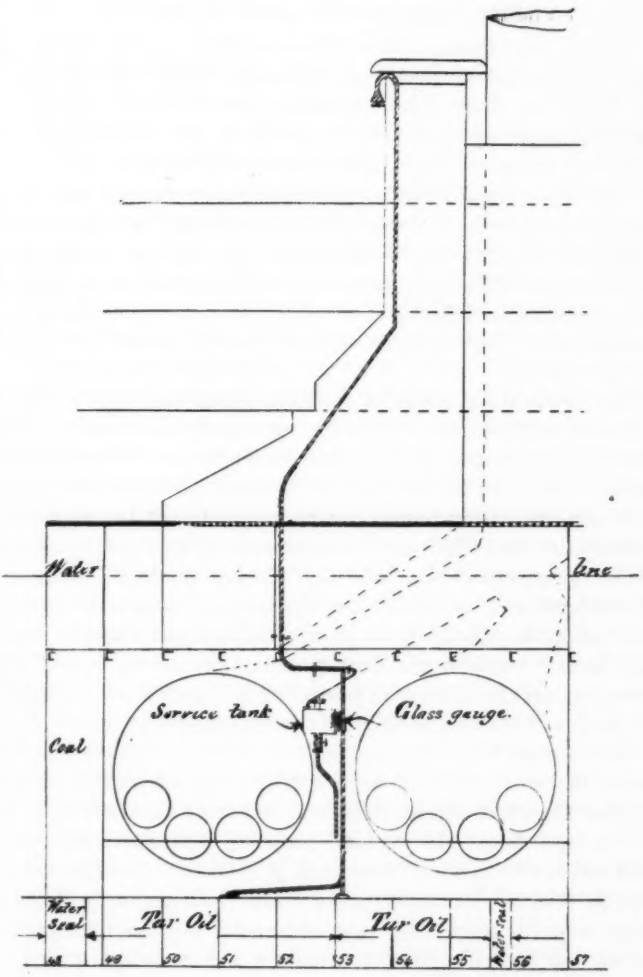
The fuel-oil tanks in the double bottom were at the time of the accident filled with fuel oil—chiefly creosote. By reason of the bending and breaking of the outer skin, the oil in these tanks was subjected, at the time of striking, to a hydrodynamic pressure, resulting in the oil being forced up the vent pipe with great velocity, and rushing out of it upon the upper deck. This also caused a rupture of the oil pipe in two places in the starboard middle fire room (compartment 8), at the height of the top of the boilers, resulting in the fire which later occurred in this compartment.

Oil also ran into the port side of compartment 6 with the water, into the fire room, and, through leaks in the longitudinal bulkhead, into the starboard fire room also, so that fires in the boilers of that compartment had also to be extinguished.

An odor of fuel oil was soon detected on the port side of compartment 8, coming in on the surface of the entering water from the bilge. On this account, the fires in the boilers of this compartment were put out, and the oil ignited; it was, however, soon extinguished, on account of the water cooling it below the temperature of ignition.

BREAKING OF THE STERN FRAME.

The breaking of the stern frame brought a great strain on the rudder, and it was feared the latter would be broken in two.



Vent pipe for Oil tanks — Filling pipe

Fig. 10

MEASURES TAKEN FOR THE SAFETY OF THE SHIP.

Fighting the Damage from Water.—After closing watertight doors, the means of combatting the danger from water by pumping it out and shoring were discussed, but it was not considered desirable to set up a counter current along the injured side, and it did not appear possible to free the ship of water.

Pumping.—An attempt was made to pump out the full boiler compartment through the port main drain pipe, by means of the center and the port circulating pumps; but the level of the water could be reduced only 1.5 meters below the highest point reached. An examination of Fig. 9 shows the reason for this: the pumps sucked as much from overboard as they did from the flooded compartment.

Meanwhile the starboard circulating pump was set to pumping out compartment 12 through the starboard main drain. After some time it became evident that compartment 6 could not be pumped out; the suction valve in that compartment was closed, and both circulating pumps put on compartment 11; then compartment 12, and afterwards compartment 11, were pumped down to the inner bottom and held so. Two of the three pumps on the secondary drain were in the flooded fire rooms, but the third was utilized for pumping out compartment 1, the water in which was sluiced into compartment 2 and pumped from it, and this compartment thereafter kept pumped out. Later it was attempted to pump out the coal bunkers of compartment 6 by means of the boiler feed-suction pipe, but without success. Everything on board that could be used for pumping was tried on these bunkers, but the effort was fruitless, and had to be abandoned.

Shoring.—Some shoring and propping were necessary in the port engine room, where bulkhead 36 (between the engine room and the flooded fire room) was bent near the bottom; in the starboard after fire room, where the middle-line bulkhead, for greater safety, was braced against the boilers, and in compartments 11 and 12—in the first, on account of a somewhat leaky cover plate in the platform deck, and in the latter to secure the manhole cover in the inner bottom. For this purpose, whatever material

could be found that was suitable was used, cutting it to the required length.

Lighting of Engine and Fire Rooms.—The electric light was turned on to the three engine rooms again, though there was much damage due to short circuits occasioned by leakage along the bulkheads, finding its way into the junction and safety fuse boxes which were fastened to the bulkheads, and so they had to depend upon emergency lights.

Fighting the Fire.—In compartment 8 the break in the oil-tank vent pipe in front of the boilers was found and stopped with packing and plugs in order to keep the oil in the tanks. But this was only partly successful, and the oil flowed in small streams through the breaks into the fire room. On this account, it was deemed advisable to haul the fires in this boiler room. The men had hardly finished this work, when the oil escaping from the broken pipe above took fire on top of the boiler and spread to the front below. Here it found further food, and soon spread over the whole fire room, so that the men had to leave. With great forethought, the men on watch had previously pumped up the boilers, and raised the safety valves, and to this circumstance is to be ascribed the fact that the boilers were not seriously injured; for the fire was receiving fresh food for some time from the fact that the glass on the oil-pressure tank had been broken by the heat and had not been noticed.

It may be mentioned here that, although the men only left the compartments which were afire at the last moment and returned immediately after the fire had been extinguished, no injury or accident to the men occurred during the entire time, newspaper reports to the contrary notwithstanding.

The fire in compartment 8 was soon extinguished by water down the ventilating trunks and by cutting off the supply of air to the fire room.

When the fire broke out, it was necessary to flood the ammunition rooms in compartments 7 and 9. The flooding arrangements worked well, and the men remained at their stations to the last moment, notwithstanding the danger from the hot bulkheads. After the fire was extinguished, these rooms, holding 135 tons,

were pumped out, which operation occupied 21 minutes. The quick emptying of these rooms might be of the greatest importance in war, because hoisting ammunition is out of the question as long as water remains in them.

Under the preceding conditions, it would be possible also during a fire to operate, by means of the port auxiliary steam pipe, the electric engines for working the 15-centimeter hoists and the hydraulic pumps for the turning gear of the 24-centimeter guns. On this account, at the time the starboard auxiliary steam pipe was in danger of burning, the usefulness of the boat-hoisting engines was in question. This is why the boats which had previously been cleared away were lowered as soon as the fire broke out, for it would have been impossible to lower them by hand in case of accident to the boat-hoisting engines.

LESSONS FROM THE ACCIDENT.

a. Main Drainage System.—The running of the main drain pipe through the double bottom, which requires its valve chambers to be placed close to the outer skin and a watertight joint to be made at each bulkhead, is an element of great danger. In such an arrangement, any serious injury to the outer skin, or to the athwartship bulkheads, through which the drain pipe passes, affects also the drain pipe, whose fastening to the inner bottom is endangered, and with it throws out the whole main drain system on that side, and makes the utility of the double bottom illusory. That this happened only to a slight extent on the *Kaiser Friedrich III* is, apart from the good material, due entirely to a happy accident. It is, therefore, necessary in future construction, that the main drain pipe run above the inner bottom. If a round pipe presents difficulties, an arrangement of oval, triangular or rectangular cross section can be used, and the objection that dirt will lodge in their corners and edges cannot be considered from a practical standpoint. In pumping from large compartments with the main drainage apparatus it has been found that for masses of water that stand from one-half to one meter above the inner bottom the main drain arrangement cannot be successfully applied, because the water does not flow quickly enough

through the valves, and the pumps soon run away. The main drain valves can be placed above the inner bottom without seriously affecting the working of the pumps. This circumstance also makes it easy to increase the safety of the entire system on vessels like the *Kaiser Friedrich III*, where the main drain pipe has been installed in the double bottom, by at least placing the valve chambers much further from the outer skin.

For new ships it is also imperative that a circulating pump or a power pump be provided in the forward part of the ship in order to give greater reserve power when damaged vessels have to make long runs at sea, and the pumps, therefore, have to be kept in use for a long time; and also to overcome the difficulty that would be encountered in pumping out an end compartment if the pumping system were thrown out of use.

b. Secondary Drainage.—This was used only for pumping out compartment 1, the water in which had been sluiced into compartment 2. It was not of sufficient capacity for pumping other compartments. In conjunction with others it would have sufficed for pumping out compartment 12, for instance, but such a pump was not at hand, except the pressure pumps used for pumping out the magazines. It is, therefore, necessary that battleships be provided with at least two electrically driven centifugal pumps. Each should be of about 50 tons capacity an hour, and of such size that they can be passed through the openings in the armored deck. With one such pump the flooded bunkers, magazines and ventilating engine room could have been quickly pumped out. These pumps can also be of good use in flooding compartments in case of fire, when flooding apparatus is not fitted, and for which the ordinary fire service would not be powerful enough. Of the three steam bilge pumps installed on the *Kaiser Friedrich III*, only one was available on account of the flooding of the port side of compartment 6 and the fire in the starboard side of compartment 8, in which compartments two pumps were located. It seems reasonable, therefore, to place one of the pumps in the forward part of the ship (compartment 10, platform deck) where the danger of flooding is least, because the platform deck can be closed watertight from below.

c. Double Bottom.—The use of the double bottom for carrying water and fuel oil did not prove so disastrous to the safety of the ship as was feared. Whether its security would remain if the outer skin were punctured by explosive bodies, is another question. However, safety demands that fuel oil be stowed as far as possible from the boiler room, and that the tanks be not filled quite full. On the contrary, it is still further necessary to have a large air chamber on the tanks. Experience has demonstrated that the present arrangement is not efficient.

The vent pipes for those double-bottom tanks that are used for the stowage of water and of fuel oil must be of the best workmanship. Soft solder, such as was used for the fuel oil pipes, should not be used. It is further desirable, if no serious constructive objection exists, to make the pipes much larger and, perhaps, of double walls, with an air space between. The vent pipe for fuel oil must, finally, be in a protected place, and always as far removed as possible from the boilers and led above them, and from their terminals ducts must lead directly overboard, so that any danger from fire by injury to the pipes may be avoided. These vent pipes should end above the water line, and not, as was the case with the pipe in compartment 10, below the platform deck, and, therefore, below the waterline.

d. Fuel Oil Installation.—The placing of the oil pumps in one room was found to be disadvantageous. After the port side of compartment 6 was flooded, in which the pumps were located next the oil-pressure tanks, there was no way of pumping the oil overboard and thus rid the ship of an element of danger. It would, therefore, not have been possible, in an engagement, to have used this oil, the greater portion of which was serviceable. By a suitable arrangement of valves each pump must be made independent of the other. Floats for determining the height of oil are to be avoided; they fail to properly indicate if the specific gravity of the oil varies. The enlarging of the vent pipe was referred to under *c.*

e. Automatic Valves.—The use of automatic float valves, such as were used in the ventilating system, designed to prevent the entrance of water in opposite directions, should be forbidden.

These valves did not work satisfactorily. The arrangement has the additional fault that two of the valves were entirely inaccessible and that their openings could not be plugged. These valves, which worked properly on the flooding tests of March 22, failed at the time of the accident and were responsible for the flooding of the ventilating system.

f. Watertight Doors.—It has been stated that compartment 6 was flooded chiefly by leakage around doors. The doors are closed by the so-called bayonet fastening, by which three dogs on either side of the door are set up by handles. In practice the dogs must be kept in better order, or a change must be made in their construction.

g. Speaking Tubes.—The arrangement of speaking tubes must be more carefully considered. When the port side of compartment 6 was flooded, the tubes for the port middle fire room (compartment 7) failed because the tubes were not tight and had filled with water. The means of transmitting orders to the port middle fire room were thus cut off.

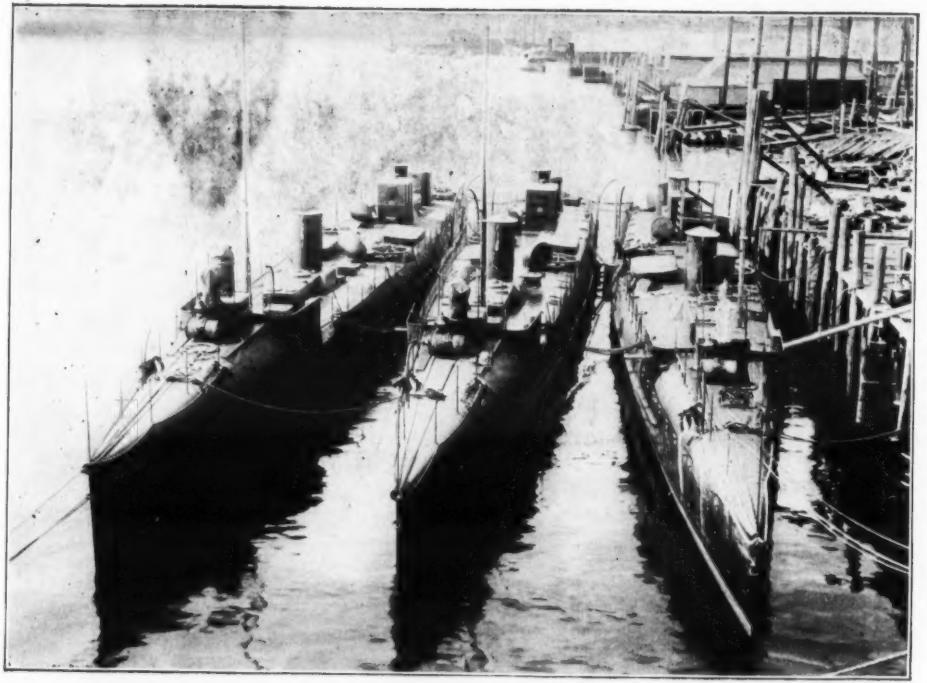
h. Electric Lighting.—As has been pointed out before, the electric light in the engine and fire rooms failed on account of short circuiting in the junction and safety-fuse boxes. The boxes, which should be watertight, did not possess this quality to any great degree, and the wire inlets to the boxes, as well also as the ducts through the bulkheads, were not tight. This part of the electric installation should, therefore, receive the most careful attention.

i. Boat-hoisting Arrangements.—The boat cranes, which are used for hoisting and lowering the large boats, are provided only with hand gear for swinging in and out. For that reason all hand gear is lacking for hoisting the boats, if from any cause the boat-hoisting machinery cannot be used. This disadvantage was keenly felt when, after grounding and the outbreak of fire, the possibility of the fire spreading to the starboard forward fire room was considered. In that case, the steam piping to the boat-hoisting engines would have been endangered, and steam would have to be shut off from these engines. It, therefore, seems reasonable to provide hand gear at least for lowering the

boats when it is not possible to use the power gear. The shafts on which the pinions for the gear wheels are secured should be provided with couplings on their free ends, so that hand gear can be applied. This would suffice at least to lower the pulling boats by means of the cranes. As the boats, if on board during an engagement, would soon be rendered useless by shot, this plan offers only a conditional advantage, and, therefore, the change is not absolutely necessary.

CONCLUSIONS.

The accident to the *Kaiser Friedrich III*, with its many complications has been fruitful in experience. The most important, however, is the reflection that our battleships, in material, construction and technical arrangement are on such a high plane that their well equipped and well disciplined personnel may be confidently trusted to manage even extraordinary matters with the utmost success.



"BAGLEY," "BARNEY" AND "BIDDLE."

U. S. TORPEDO BOATS *BAGLEY, BARNEY* AND *BIDDLE.*

By Mr. Charles P. Wetherbee.

The U. S. torpedo boats *Bagley, Barney* and *Biddle* were designed and built by the Bath Iron Works, Bath, Maine, in conformity with the circular issued to bidders defining the characteristics of sixteen torpedo-boat destroyers and twelve torpedo boats. This circular will be found on pages 817 to 825 of Volume 10, Number 3, of the Journal.

These three vessels are the only ones of the twelve torpedo boats that were built entirely from the contractors' plans and specifications, the others being built from those prepared by the Navy Department.

The principal dimensions of the vessels are as follows:

Length on trial L.W.L., feet and inches	157
over all, feet and inches	157- 4
Beam at deck, feet and inches	15- 6
at waterline, feet and inches	16- 2¾
extreme, feet	17
Depth amidships from keel to crown of beam, feet and inches	10- 9
Molded depth at side, feet	10
Average draught of hull on trial, forward, feet and inches	4- 8½
aft, feet and inches	4-11½
mean, feet and inches	4-10
Mean displacement on trial, tons	168
Tons per inch immersion	4.4
Moment to alter trim 1 inch, foot tons	38.4
Area of trial water plane, square feet	1,892
Center of gravity of trial water plane abaft midship section, feet	7.25
buoyancy abaft midship section, feet	1.50
above base, feet	3.09
Transverse metacenter above center of buoyancy, feet	4.96
base, feet	8.05
Center of gravity above base (trial condition), feet	6.10
Transverse metacentric height (trial condition), feet	1.95
Block coefficient for displacement	.478

Midship section coefficient	.724
Coefficient of trial water plane	.743
Wetted surface, square feet	2,540

The armament consists of three 3-pounder semi-automatic R.F. guns and three tubes for short 18-inch Whitehead torpedoes. Ample ammunition is carried for the guns, and there is provision for carrying five torpedoes.

There is a conning tower forward, made of half-inch nickel-steel with a searchlight mounted on top of it.

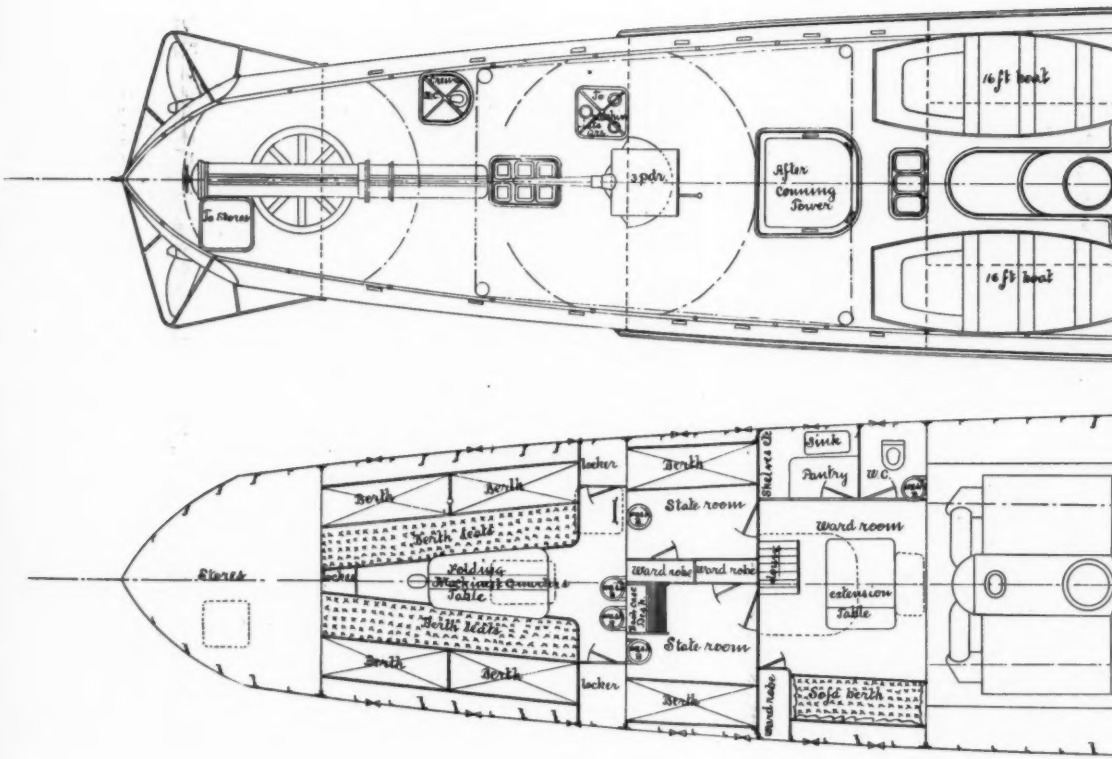
There are eleven large watertight compartments, separated by transverse bulkheads. Some of these compartments are further subdivided by longitudinal bulkheads, making a total of fifteen watertight divisions in all. The two compartments at the middle of the boat are occupied by the main engines with their condensers and auxiliaries. Just forward and just aft of these are the boiler compartments, each containing one boiler and the usual fire room auxiliaries. Coal bunkers having a total capacity of forty-seven tons are located on each side of the boilers and on one side of each engine room.

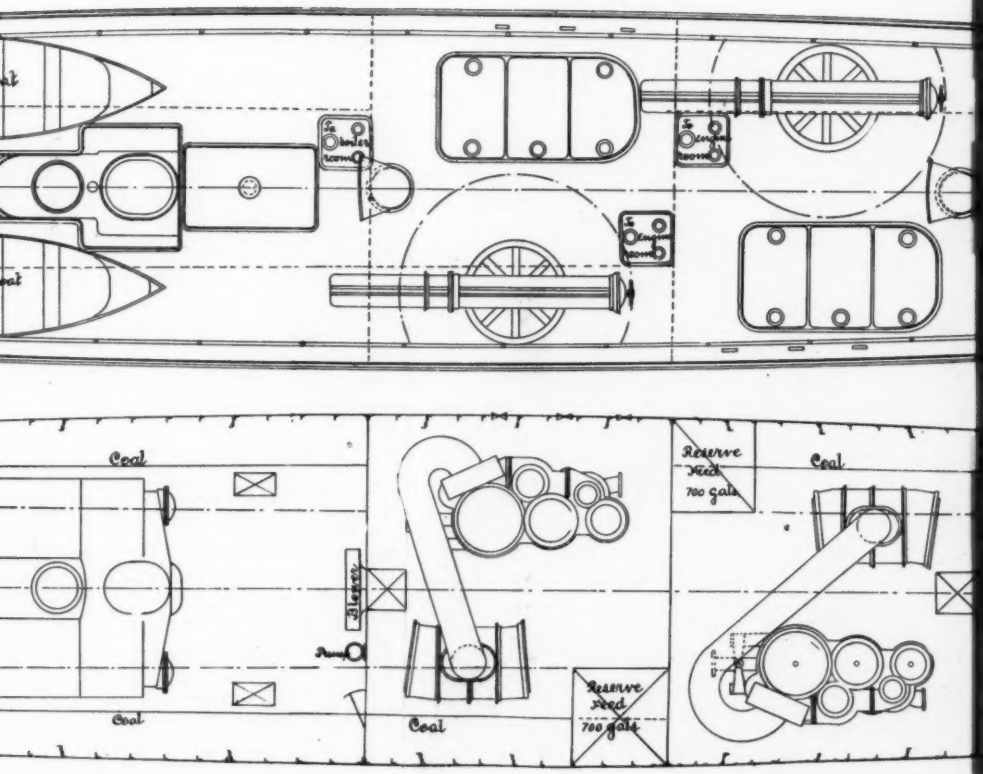
The two compartments forward of the forward boiler are occupied by the crew, while the one just aft of the after boiler is devoted to the officers, and the one aft of that to the petty officers. Accommodations are provided for three officers and twenty-six crew.

Steam heat is fitted in the living spaces. There is a combined hand and steam-steering gear, and a steam windlass made by the Hyde Windlass Company. There is also an electric-light plant of about sixty lights capacity, including a searchlight.

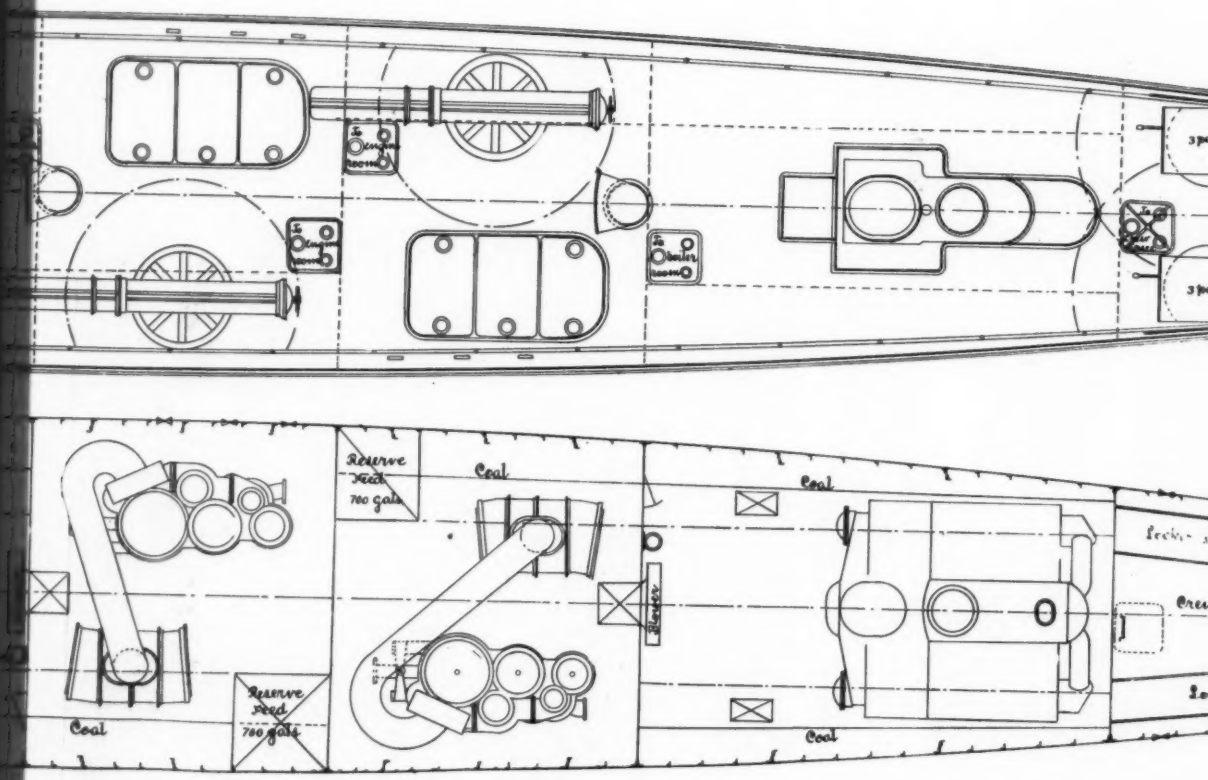
The vessels are very lightly constructed, and still are exceedingly strong. The freeboard is considerably lower than that used on the torpedo boats of the Department's design, appreciable weight being saved by this reduction. The general arrangement of the vessels is clearly shown in the accompanying plans.

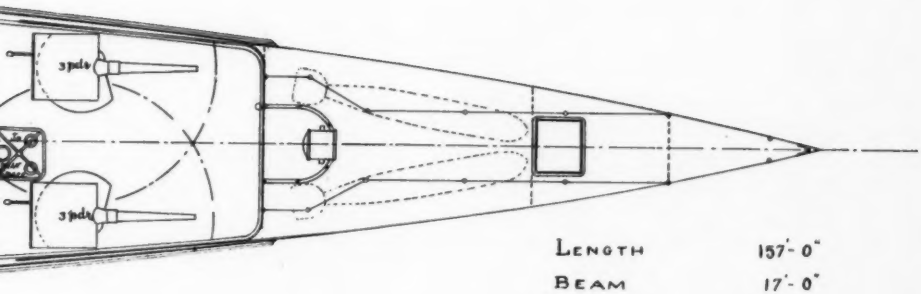
The propelling machinery, of the Normand type, consists of two vertical, inverted, three-cylinder, triple-expansion engines, which are quite clearly illustrated in the accompanying photographs. These engines operate twin screws having 6.68 feet


16 ft boat
3 pdr
After Conning Tower
16 ft boat
Berth
Berth
Berth
Berth
Locker
Berth
Sideboard
Sink
Pantry
W.C.
State room
Ward room
Ward robe
Ward robe
Mess
extension Table
State room
Locker
Berth
Ward robe
Sofa berth

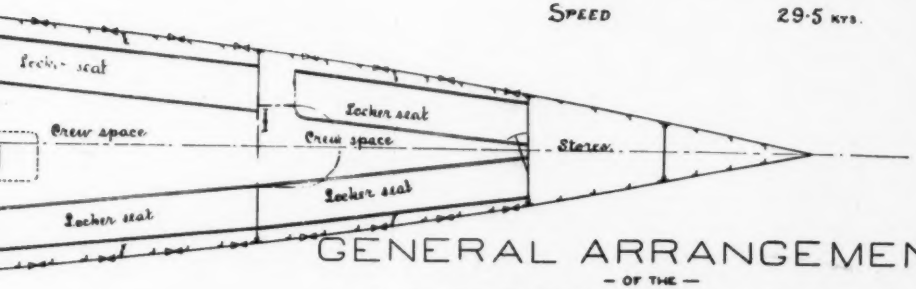

Boiler room
Engine room
Engine room

Coal
Bunker
Coal
Coal
Reserve feed 700 gals
Reserve feed 700 gals
Coal


Reserve
Feed
700 gals
Coal
Reserve
Feed
700 gals
Coal
Heater
Coal
Coal



LENGTH	157'-0"
BEAM	17'-0"
DEPTH	10'-9"
MEAN DRAFT	4'-7½"
I-H-P-	4200
SPEED	29·5 KTS.



GENERAL ARRANGEMENT

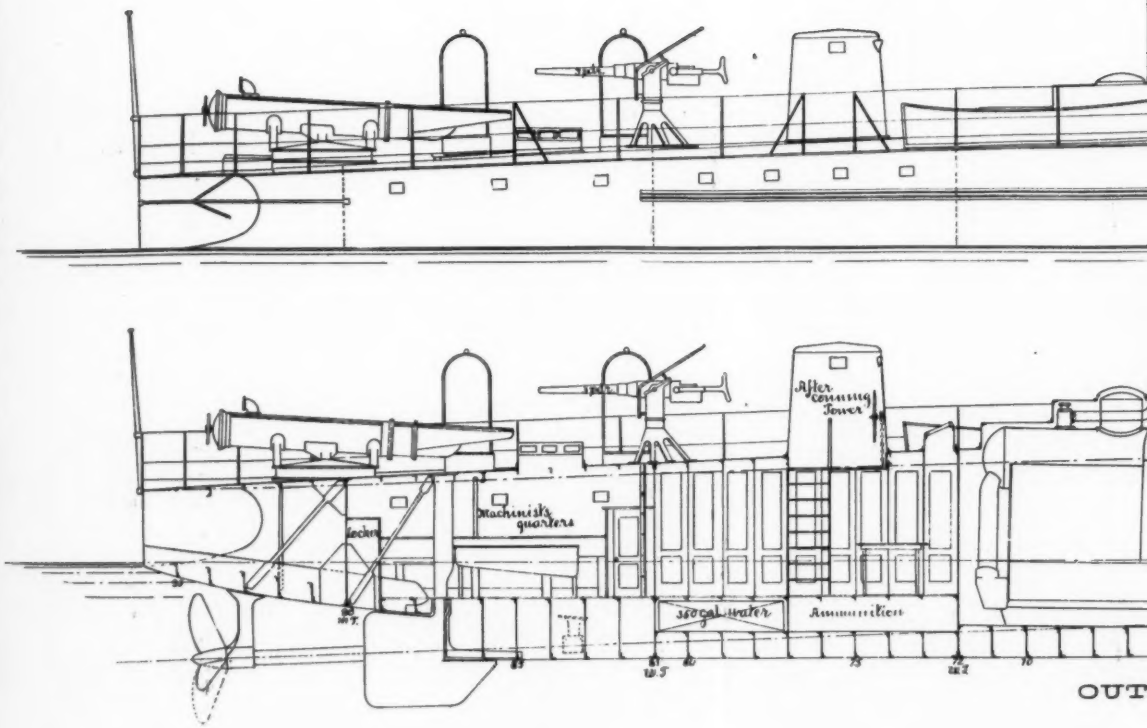
— OF THE —

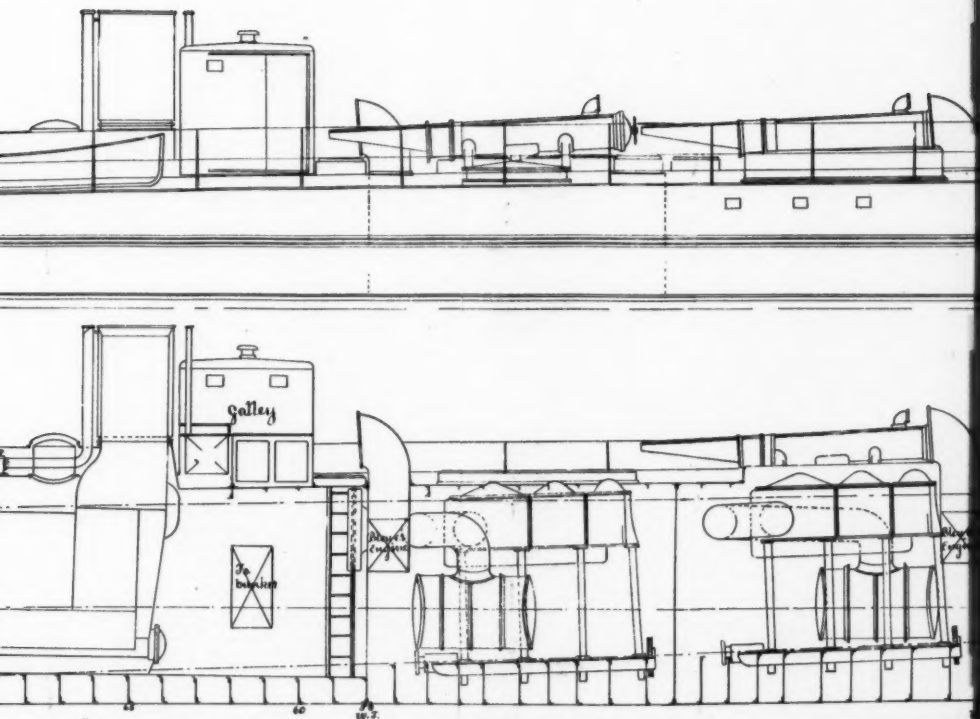
U-S-TORPEDO-BOAT NO. 24.

"BAGLEY"

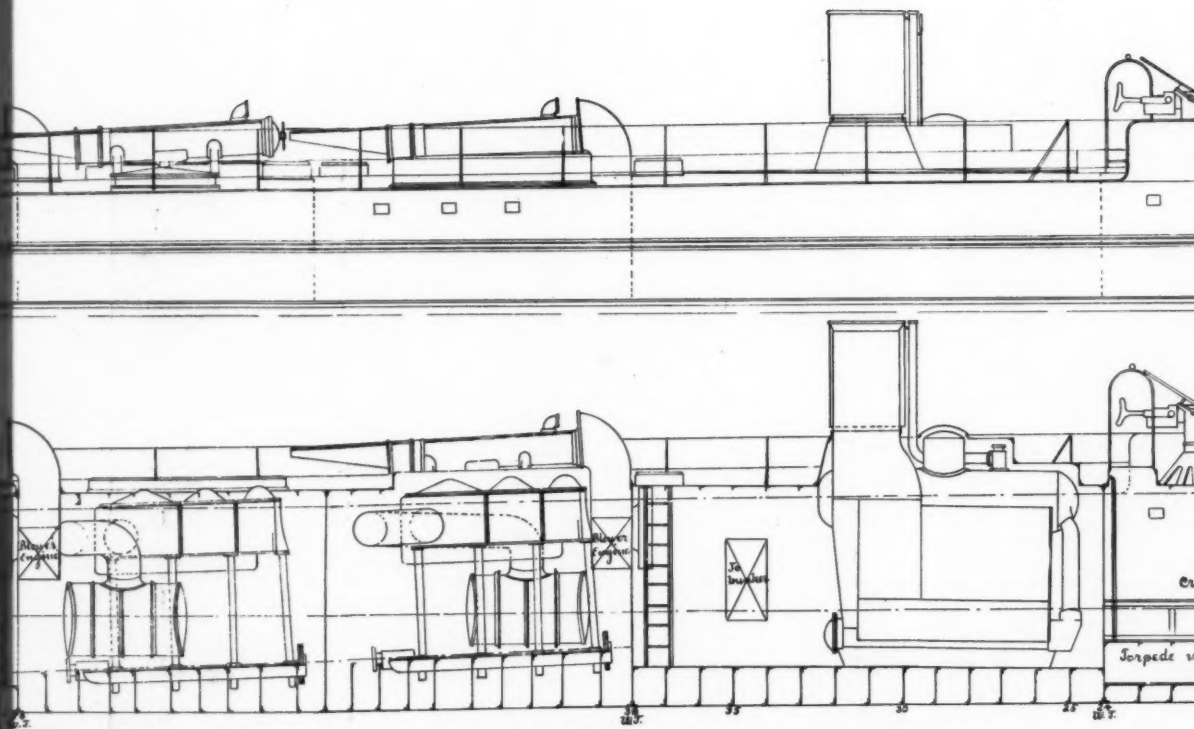
BATH IRON WORKS. BATH ME. JAN 21 -1899.

PLAN 771 SCALE - ½ IN. = 1 FOOT.

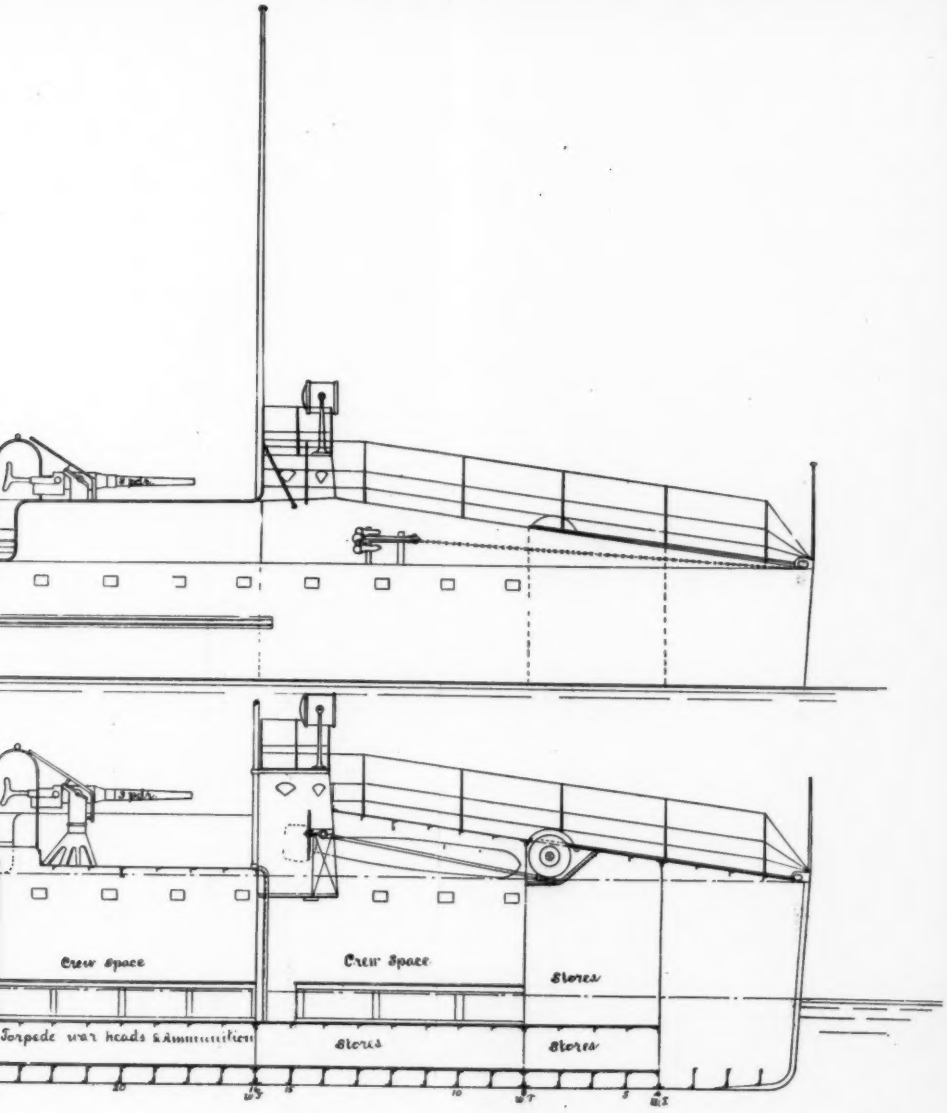

After conning Tower
Machinists quarters
Lecken
350 gal. water
Ammunition
OUT

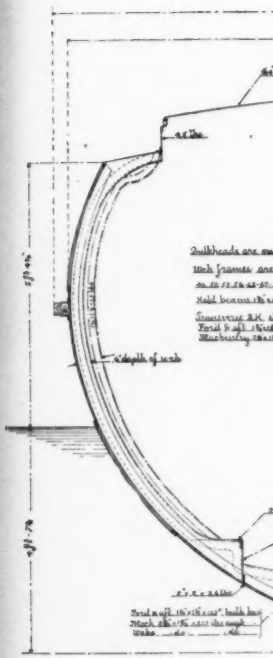


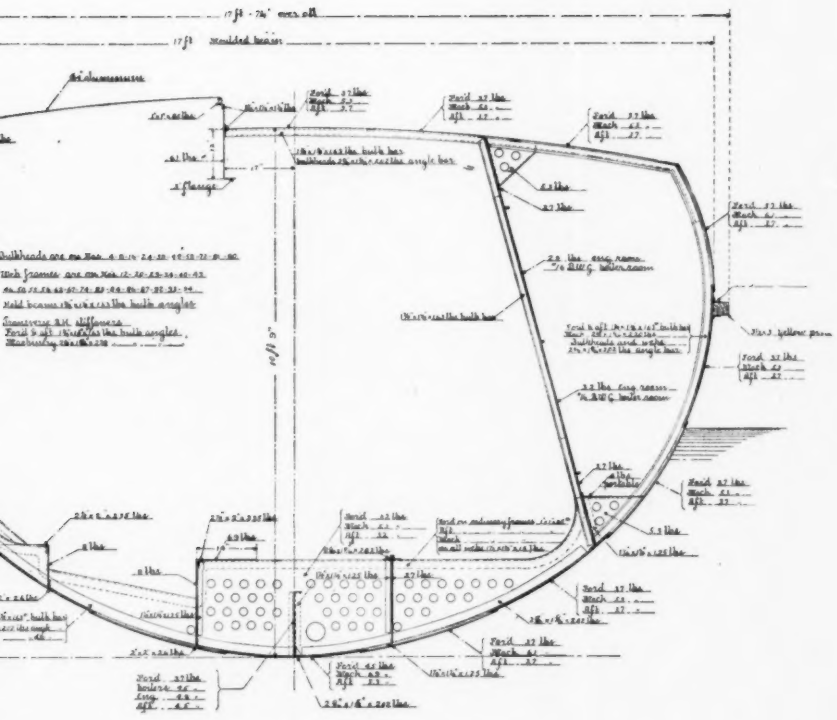
OUTBOARD AND INBOARD PROFILE U. S. TORPED



INBOARD PROFILE U. S. TORPEDO BOAT "BAGLEY."


Crew space
Crew Space
Stores
Stores
Stores




17ft · 7½" over all
17ft moulded breadth
Bulkheads are on Nos. 4 8 12 16 20 24 28 32 36 40
Web frames are on Nos. 12 16 20 24 28 32
44 48 52 56 60 64 68 72 76 80 84 88 92 96 100 104
Mild beams 18"x6"x½" the bulb angles
Transverse Rib stiffeners
Ford 9 off 18"x6"x½" the bulb angles
Machinery 18"x6"x½"
Ford 27 lbs
Mach 22
Aft 17
18"x6"x½" the bulb bar
Bulkheads 18"x6"x½" the angle bar
27 lbs
22 lbs
Ford 9 off 18"x6"x½" the bulb bar
Bulkheads aft 18"x6"x½"
24"x6"x½" the angle bar
Ford 27 lbs
Mach 22
Aft 17
22 lbs
Ford 27 lbs
Mach 22
Aft 17
6 lbs
18"x6"x½" the bulb bar
Ford 27 lbs
Mach 22
Aft 17
Ford 27 lbs
Mach 22
Aft 17
Ford 27 lbs
Mach 22
Aft 17

diameter and 10.88 feet pitch. The sizes of the engines are, high-pressure cylinder, 17.22 inches; intermediate pressure, 24.78 inches; low pressure, 37.37 inches, with a common stroke of 21 inches. These engines are capable of working up to 335 revolutions per minute, but it was not found necessary in these vessels to drive them at such a high number of revolutions to obtain a speed considerably in excess of the contract requirements.

There are two Normand water-tube boilers, each having a grate 9 feet and 6 inches long and 6 feet 3 inches wide, with a heating surface of 2,800 square feet, supplying steam to the engines at a pressure of 230 pounds to the square inch.

There are two condensers, one being in each engine compartment. Each condenser has a cooling surface of 1,183 square feet. The tubes in these condensers are curved and expanded into the tube sheets, thus overcoming the usual difficulty with leaky tubes, and increasing the efficiency of the condensers. Sea water is circulated through the condensers by means of scoops, the motion of the vessel being sufficient for the circulation without any pump being in use. There is, however, a small circulating pump supplied for each condenser for use when the vessel is standing still.

The air, feed and bilge pumps are driven by shafts taking their motion from the intermediate crosshead of each main engine. The feed water from the main feed pumps is sent through closed heaters on its way to the boilers. These heaters take their steam from the low-pressure steam chests at the working pressure of those chests, which at full power is from 22 to 28 pounds. The heaters are very efficient; they raise the temperature of the feed water about 115 degrees, it being delivered to the boilers between 225 and 240 degrees Fahrenheit.

The main engines are all steam jacketed, both barrels and heads, and steam is used at boiler pressure for this purpose, except in the case of the low-pressure barrel jackets, which are supplied from the intermediate steam chests at a pressure of about 90 pounds, and drain back to the same chests. The steam for the other jackets is taken from the bottoms of the separators

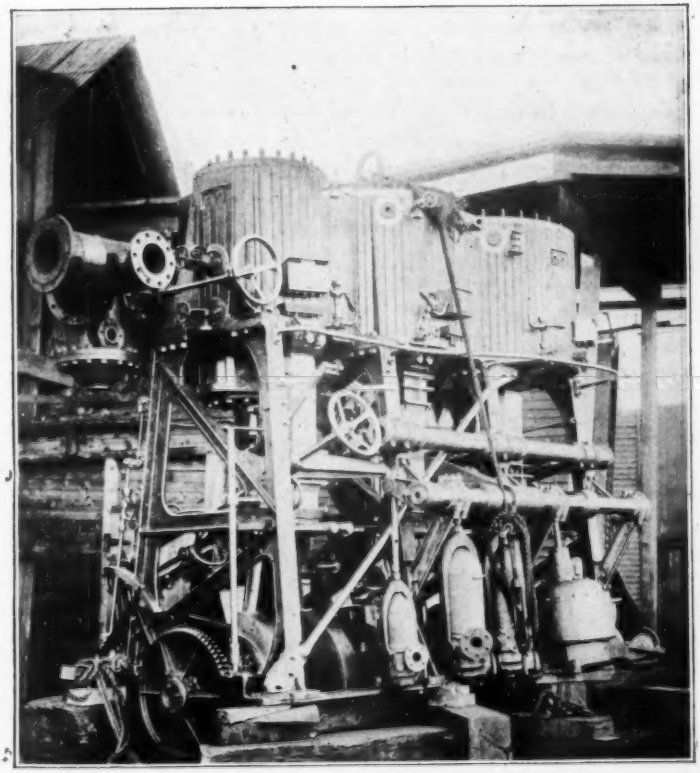
at the main engine throttle valves, and after passing through the jackets is used to drive the blower engines. The exhaust from these blower engines can be turned either into the condensers direct or into the low-pressure steam chests, by means of valves provided for turning the auxiliary exhaust into one of these discharges or the other, as desired.

While the piping is arranged so that both boilers can supply steam in common to both engines, and so that either boiler can supply steam to both engines, in case of running a single boiler, yet the way that this piping is designed to be used in full power service, or any service where both boilers are in use, is to entirely separate the forward boiler, forward engine and condenser from the after boiler, after engine and condenser, thus making two independent steam plants in the vessel. This system avoids the usual difficulty in maintaining a constant level of water in the boilers, because each boiler, engine and condenser, with the coupled pumps, form a closed circuit having a constant amount of water in it, which amount is only reduced by leakage. In order to make up for this leakage, a small pipe is led from the reserve feed tank to the condenser and a valve on this pipe is under the control of the water tender in the fire room. By this means, the amount of water turned into the condenser from the reserve-feed tank can be regulated so that it just equals the amount lost by leakage, and the water level in the boiler remains absolutely constant.

Each fire room is fitted with a 55-inch blower, a Davidson ash ejector and an auxiliary feed pump capable of feeding both boilers at their maximum capacity.

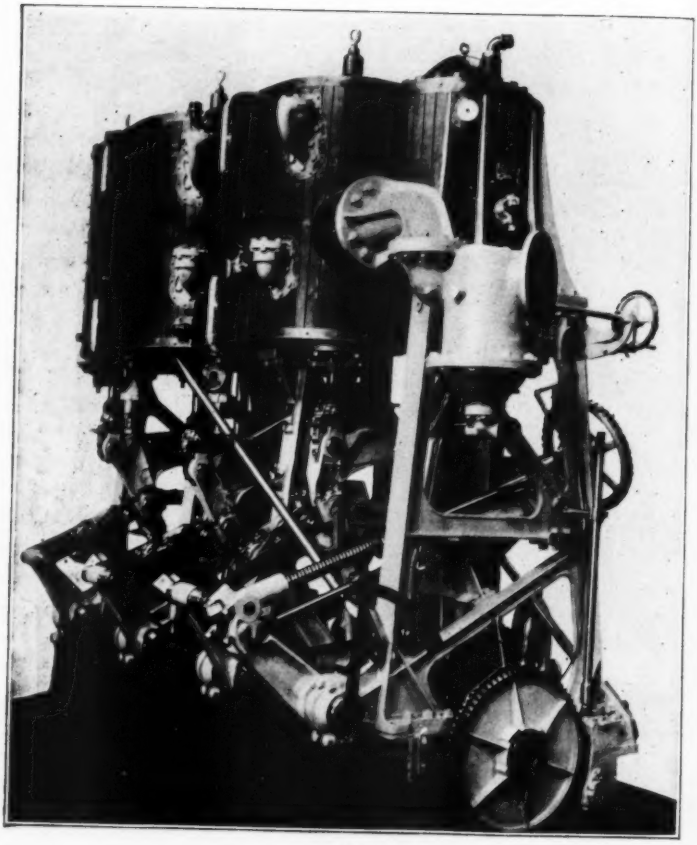
Each engine room is provided with an evaporator having a capacity of 1,000 gallons in 24 hours, and the after engine room is fitted with a distiller having a capacity of 1,000 gallons in 24 hours.

Many skeptical remarks have been made about the enormous power obtained from this machinery with such comparatively small boilers, but the reason for it is the great steam economy obtained by means of the various arrangements described above and summarized in detail as follows:



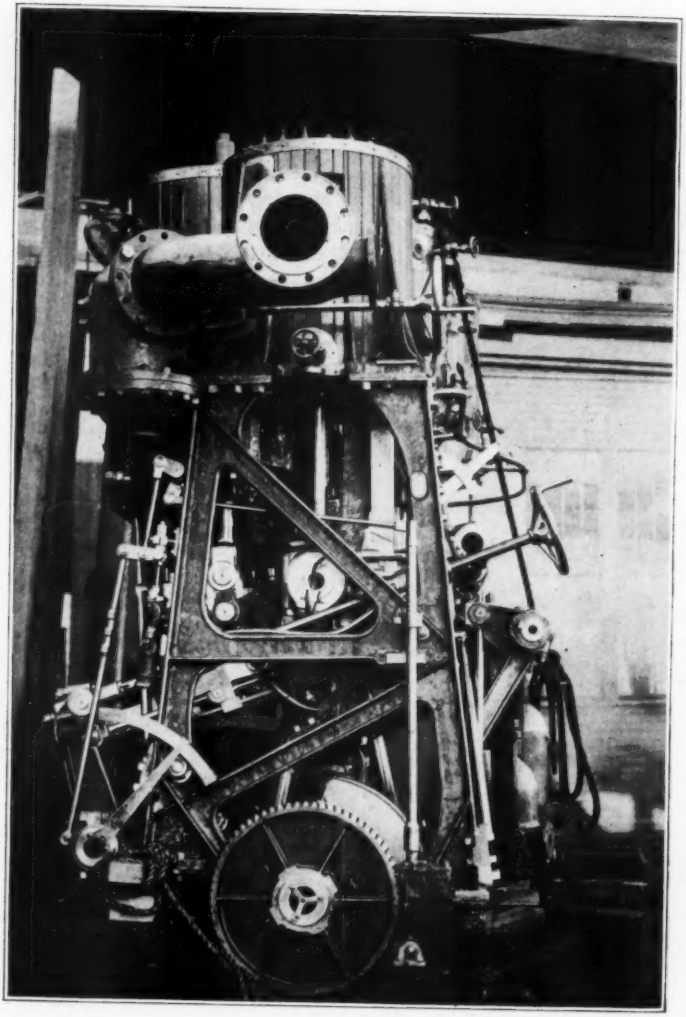
U. S. S. "BAGLEY."

STARBOARD ENGINE——INBOARD SIDE.



U. S. S. "BAGLEY."

STARBOARD ENGINE——OUTBOARD SIDE.



U. S. S. "BAGLEY."

STARBOARD ENGINE—FORWARD END.

(*a.*) Absolutely constant height of the water in the boiler, obtained without any feed regulators. This enables the boilers to steam uniformly at their maximum capacity at all times, because the boilers are not pumped full of cold water one minute and nearly empty the next.

(*b.*) The combustion is carried on at all times at its utmost rate, with the firemen perfectly at their ease and having the confidence which is given by a constant and adequate supply of water to the boilers.

(*c.*) The water is fed to the boilers at a temperature averaging 235 degrees Fahrenheit.

(*d.*) The engines are exceedingly long stroke and steam jacketed by a simple system which is far more efficient than the usual complicated method involving reducing valves and traps.

(*e.*) The jacket steam is used to drive the blowers.

(*f.*) The engines are of the three-cylinder type instead of the four, thus having considerably less cylinder wall for condensation and re-evaporation in proportion to the volumes of the cylinders. The use of the three-cylinder engines is made without the corresponding loss of balance so frequently claimed to be inherent to this type of engine. The running parts of each cylinder are made as nearly as possible the same weight, with the result that the balance is far better than that obtained with the four-cylinder engine, with the cranks opposite.

(*g.*) The clearance spaces are very small, being 11.7 per cent. in the high pressure, 15.7 per cent. in the intermediate and 7.8 per cent. in the low-pressure cylinders.

The official speed trials of these three vessels were all conducted without the slightest accident of any kind, and the contract speed was exceeded with the greatest ease. Each vessel had her propellers standardized on the measured mile at Southport, Maine, and the revolutions per minute found necessary to propel the vessels at 28 knots when loaded as required by the contract are given on page 659.

The official two-hour speed trials were conducted in the open sea, taking place as follows:

Name.	Date.	Official mean speed.
Bagley, . .	May 10th, 1901,	29.15 knots.
Barney, . .	May 15th, 1901,	29.04 knots.
Biddle, . .	July 2d, 1901,	28.57 knots.

The run started from near Seguin Island, at the mouth of the Kennebec River, running over to Wood Island, off Old Orchard Beach, Maine, then, with a long turn, coming back to Seguin. The distance is such that the total elapsed time was two hours in each case. The turn was included in the official time and revolutions.

Appended are the results of these trials in tabular form.

U. S. T. B. *BAGLEY.*

STARBOARD ENGINE.

Time.			Mean revolutions per min.	Steam pressure above atmosphere.				Vacuum.	Air pressure.
				Steam pipe.	H.P. valve chest.	1st receiver.	2d receiver.		
h.	*m.*	*s.*						*inches.*	*inches.*
11	13	30	...	200	197	81	22	22.75	5.4
	28	30	304.27	215	210	86	24	22	5.8
	43	30	302.87	210	204	85	23	22.25	6
	58	30	303.33	215	210	87	23	22.75	5.7
12	13	30	305	215	209	87	23	22.50	6.3
	28	30	305.46	220	210	88	24	21.25	6.3
	43	30	310.47	225	218	90	25	21.25	6.3
	58	30	308.60	215	210	87	23	21.75	6.3
1	13	30	306	203	199	82	23	21.25	*6.4
Mean.....			305.75	213.1	207.5	85.9	23.3	21.97	6.1

Temperatures: Injection water, 50 degrees; discharge water, 81.3 degrees; hotwell, 101 degrees; feed water, 232 degrees.

PORT ENGINE.

11	13	30	...	235	230	95	27.5	19.5	6
	28	30	309.32	240	235	102	26	22	5.5
	43	30	302.73	240	235	102	26	22	5
	58	30	304	240	235	100	25	22	5.5
12	13	30	302.60	235	230	99	25.5	21.5	3.5
	28	30	318	225	219	96	27	21	5.5
	43	30	318.92	215	210	92	19.5	22	6
	58	30	321.60	225	219	97	27	20.5	6
1	13	30	322.87	235	230	100	27	20.5	6
Mean.....			312.48	232.2	227.0	98.1	25.6	21.2	5.44

The *Bagley* was not run at full power for the first hour of the two-hour run. Care was taken only to maintain her speed slightly in excess of 28 knots, but on the second hour she was allowed to run at full speed, the revolutions showing that she made 29.71 knots as an average for this hour, *and during the last five minutes of this hour, after the vessel had been running an hour and fifty-five minutes, the speed was 30.14 knots.* The average indicated horsepower for the two hours was 3,920 and the maximum was 4,200.

U. S. T. B. *BARNEY.*

STARBOARD ENGINE.

Time.		Mean revolutions per min.	Steam pressure above atmosphere.				Vacuum.	Air pressure.
			Steam pipe.	H.P. valve, chest.	1st receiver.	2d receiver.		
h.	*m.*						*inches.*	*inches.*
3	34	...	198	165	66	12	22.75	3
	49	299.53	198	194	66	19	23	3.2
4	04	302.60	203	199	76	21	23	3.3
	19	306.53	203	199	76	21	22.5	3.2
	34	304.33	215	210	86	24	22	4.1
	49	308.20	210	199	81	22	22	4
5	04	309.73	210	199	81	22	22.5	3.8
	19	301.73	198	190	76	20	23	3.2
	34	302.20	203	190	81	20	23	4
Mean.....		304.358	204.2	193.9	76.6	20.1	22.6	3.5

Temperature: Injection water, 43 degrees; discharge water, 72 degrees; hotwell, 110 degrees; feed water, 232 degrees.

PORT ENGINE.

3	34	...	231	215	100	29½	23	6
	49	314.27	226	212	95	28½	23	6
4	04	325.72	228	215	95	29½	23½	6½
	19	324.93	220	203	93	27½	23½	6½
	34	318	220	215	95	28½	23½	6
	49	321.67	226	220	100	28½	23	6
5	04	321.60	220	215	98	27	23½	6
	19	319.40	220	215	99	28½	23½	6
	34	317.53	215	203	97½	28	23	6
Mean.....		320.267	223.1	212.55	96.9	28.4	23.26	6.1

The *Barney* was run at full power throughout the trial, as it was conducted in a sea which was quite heavy for a torpedo

boat; she frequently jumped so that from twenty to thirty feet of the forward part of the keel was entirely out of water, and things were very wet on deck. The average indicated horsepower for the two-hour run was 3,910.

U. S. T. B. *BIDDLE.*

STARBOARD ENGINE.

Time.	Mean revolutions per min.	Steam pressure above atmosphere.				Vacuum.	Air pressure.
		Steam pipe.	H.P. valve chest.	1st receiver.	2d receiver.		
h. m. s.						*inches.*	*inches.*
A. M.							
11 51 30							
P. M.							
12 06 30	300.67	229	...	88	24	22	3.2
21 30	305	231	...	91	24	22	4
36 30	306	220	...	90	24	22	4.1
51 30	305.67	220	...	90	23	22	4.8
1 06 30	307.67	220	...	88	22	21	...
21 30	307	225	...	90	23	22	...
36 30	307	220	...	88	23	22	...
51 30	307.47	225	...	85	23	21	...
Mean.....	305.8	223.75	...	88.5	23.25	21.75	...

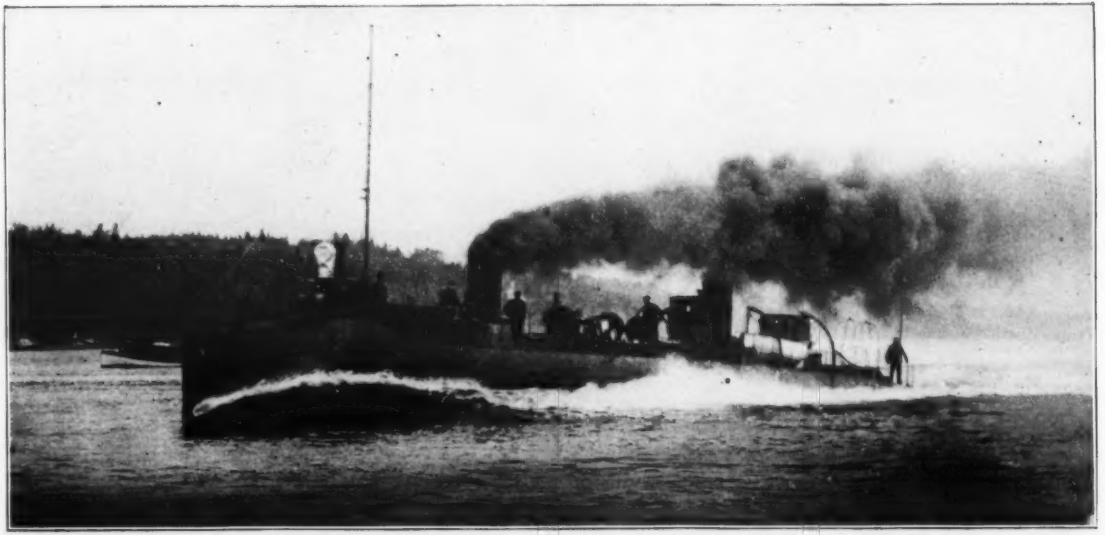
Temperatures: Injection, 60 degrees; discharge, 80 degrees; hotwell, 118 degrees; feed water, 234 degrees.

PORT ENGINE.

11 51 30 P. M.	...	227	224	92	27.5	19	4.8
12 06 30	306.67	231	226.5	96.5	27	20.5	3.9
21 30	307.60	232	232	95	27	20.5	3.5
36 30	307.87	232.5	230.5	93.5	25.5	20.5	3.35
51 30	307.93	227	226	90	25.5	18	2.8
1 06 30	306.80	223.5	223	93.5	24.75	22.25	4
21 30	307.93	223	221	92	24.5	23.5	3
36 30	307.87	224.5	222.5	90.5	24.75	21.5	3
51 30	308.13	220	220	90	24	22.5	3
Mean.....	307.6	226.8	225.1	91.44	25.61	20.92	3.48

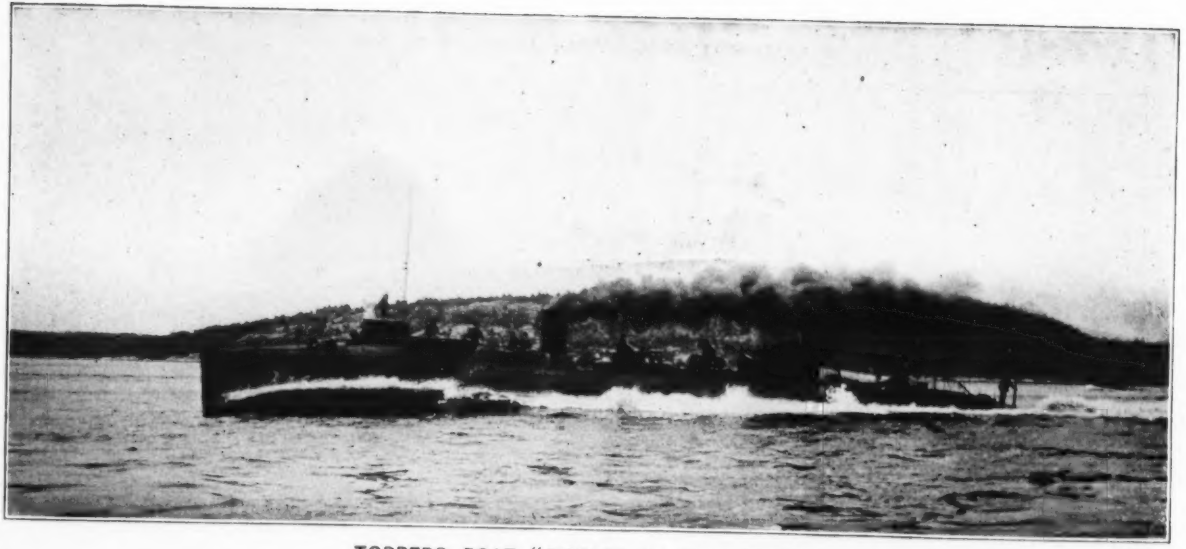
Temperatures: Injection, 61 degrees; discharge, 79.5 degrees; hotwell, 114.2 degrees; feed water, 228 degrees.

The *Biddle* had her standardization trial and her two-hour sea trial on the same day, with only sufficient time elapsing between the two trials to enable the vessel to take on sufficient coal to



TORPEDO BOAT "BIDDLE" AT FULL SPEED.

Photograph copyrighted by C. R. Higgins, Bath, Maine.



TORPEDO BOAT "BIDDLE" AT FULL SPEED.

Photograph copyrighted by C. R. Higgins, Bath, Maine.

replace the weights consumed during the standardization trial and to compensate for the coal which would be consumed in getting up to speed before the official two-hour run began. The boilers and fires were not cleaned between the standardization trial and the two-hour run. The *Biddle* was at no time driven to anywhere near her maximum speed. The speed of the engines was adjusted so that the vessel would maintain a speed slightly in excess of 28 knots, and the quantity of steam supplied by the boilers was regulated by the speed of the blowers, no attempt being made to force her. The safety valves popped frequently during the entire two hours. The average indicated horsepower for the two-hour run was 3,650.

The revolutions per minute necessary for the contract speed of 28 knots were:

	Revolutions per minute.	Per cent. slip.
Bagley, ...	297.6	12.4
Barney, ...	301.35	13.5
Biddle, ...	301.7	13.5

The accompanying photographs show the *Biddle* at full speed, and it will be noted that in smooth water these vessels do not lift the fore foot out of water as torpedo boats usually do. The change of trim on these vessels is 52 inches at full speed. The entire designed water-line length is available at full speed, so that the resistance of the vessels does not increase as fast in proportion as does that of some other types.

The load carried on trial by these vessels was not reduced in any way from that originally contemplated by the contract, the weight at the commencement of the two-hour trial for each being as follows:

Hull complete, tons	47
Machinery complete with water, but not reserve feed, tons	91
Reserve feed water, tons	5
Trial load required by contract, tons	27
Total, tons	170

The consumption of coal and water during the trial reduced the weights on board about 4 tons, so that the mean displacement on the two-hour trial was 168 tons.

All three of these vessels finished the two-hour trial in perfect condition to run another hour had it been necessary, and in fact the boats were run at full speed for a considerable time after the two hours had elapsed in order that turning trials might be made at full speed.

There was no flaming at the stack on any of these vessels. The coal consumption per indicated horsepower was exceedingly low on all of them, being as follows:

	Pounds per hour.
Bagley, ...	2.06
Barney, ...	2.09
Biddle, ...	1.89

These figures, obtained while burning from 55 to 65 pounds of coal per square foot of grate per hour, are truly wonderful and are without parallel in the history of torpedo-boat construction in this country or in England. The consumption of coal was very accurately determined, as all the coal used was carried in bags holding 76 pounds each, and the number of bags emptied on the official two-hour speed trial was recorded by the naval officers connected with the trial and checked by the contractors.

This low coal consumption is the secret of speed in these vessels, and, taken in conjunction with the remarks previously made concerning steam economy of this class of machinery, makes the strongest plea possible for its use on all fast vessels, either torpedo boats or yachts. The solidity and perfect running of the engines and boilers, combined with their durability, are also strong arguments in favor of its more general use, which will certainly take place as soon as its merits are generally known.

ON THE LIMITS OF ECONOMICAL SPEED OF SHIPS.

By Mr. E. Tennyson-D'Eyncourt.

[Paper read before the Institution of Naval Architects.]

A wish has frequently been expressed at meetings of this Institution that members would give results of their experience derived from the actual performances of vessels on progressive trials, and the methods they adopt in estimating the power necessary for driving ships at given speeds; more especially was this the case when Mr. James Hamilton read his paper on "Horsepower deduced from Progressive Trials," some three years ago.

I have, therefore, endeavored to bring into line the data obtained from a large number of progressive trials of ships of different forms, and to derive certain broad, practical rules from these data, which may, I trust, be of interest, and may possibly elicit the results of their experience from others who have made a study of the question.

I think it has, perhaps, been too common a practice in fixing the speed for a vessel, and in estimating the necessary indicated horsepower for that speed, to overlook the question of what speed is appropriate to the form of vessel under consideration, and to go upon the broad basis of allowing plenty of margin of horsepower, with the result that often too high a speed has been aimed at and too much power has been allowed. As a necessary consequence, the weight and cost of the excess has been a continual burden upon the earning capacity of the ship. This was, perhaps, very well when competition was not so keen; but nowadays, when cost has to be cut down to a minimum in every direction, not only by the shipbuilder, but also by the shipowner, the question of giving a ship enough, and not too much, power and speed has become one of first importance.

It is necessary to bear in mind the fact that every ship has an appropriate limit of speed, beyond which it is most uneconomical to attempt to drive her; or, in other words, any increase of speed beyond this limit requires an undue increase of power. It has, therefore, been my object to arrive at a method of defining this limiting speed for ships of different sizes and different forms.

To attempt to arrive at a general solution to meet all cases is, I need hardly say, an impossibility; but I venture to think that a fair approximation to the suitable power and speed may be arrived at by a consideration of the general principles governing the relation between the dimensions and form of ships on the one hand, and the appropriate speed and power on the other.

To obtain accurate values it is, of course, necessary to consider each case individually upon its own merits; to have the exact form of the underwater body, and a record of the performance of a similar ship, or of model experiments.

In analyzing the trial results which I have had at my disposal, I have not attempted to divide the indicated horsepower absorbed into all the heads, which, in making an exhaustive analysis, would, perhaps, be necessary; but I have, for the sake of ease in comparing the performances of different vessels, always assumed the effective horsepower to be half the indicated horsepower. This is a somewhat crude method, perhaps, but, I think, as good as any other, where so many unknown (or at least doubtful) quantities are involved. I think, also, this is a fair average value to assume for the propulsive coefficient, with modern triple or quadruple-expansion machinery and suitable propellers, at the higher speeds which I am considering. Having, therefore, made this assumption, I have proceeded to calculate the horsepower absorbed by skin friction on the basis given by the late Mr. Froude, and now universally adopted; and the difference, after deducting the skin horsepower from the effective horsepower at any speed, gives the power necessary to overcome the so-called residuary resistance, which at the higher speeds is principally caused by wave making. For brevity's sake this may be termed the wave horsepower.

The different values of the wave horsepower obtained by this

method for similar ships, and in some cases for sister ships, show up the variations in the value of the propulsive coefficient of propeller efficiency, etc., actually occurring in practice; but the merit of the method lies in the fact that it gives a definite comparison between the performances of different ships. The naval architect must make allowance for the efficiency of machinery, etc., as experience dictates. Having obtained curves in the manner indicated for many ships of varying dimensions, forms and degrees of fineness, I have been able to deduce the general results shown in the table below. This gives the coefficient of fineness and the amount of parallel body which may be associated with that coefficient, and the corresponding limiting economical speed, expressed as a percentage of the square root of the length of the ship in feet on the water line.

Coefficient of fineness.	Parallel body as percentage of total length of ship on W.L.	Limiting economical speed in knots as percentage of $\sqrt{L}$, in feet.
·5	0	100
.6	14	86
·7	30	68
.8	49	48

Figure I shows these values in curves *PP* and *LL*. The former gives the appropriate length of parallel body, which is equivalent to giving the combined lengths of entrance and run; and it will be seen that the percentage values of $\sqrt{L}$ for the limiting economical speed are practically the same as the percentage values of the combined length of entrance and run. This agrees with the value which has been given previously for vessels with no parallel body, but gives a smaller economical speed for vessels with parallel body, the previous rule having been that the economical speed is equal to the square root of the sum of the lengths of entrance and run, and it seems to show that a penalty must be paid for introducing parallel body.

Taking actual trial results, I find that the indicated horse-power at the limiting speed, as defined above, is varying as the fourth power of the speed, and varies, in increasing ratio, till at about 12 per cent. above the limiting speed it is varying as the

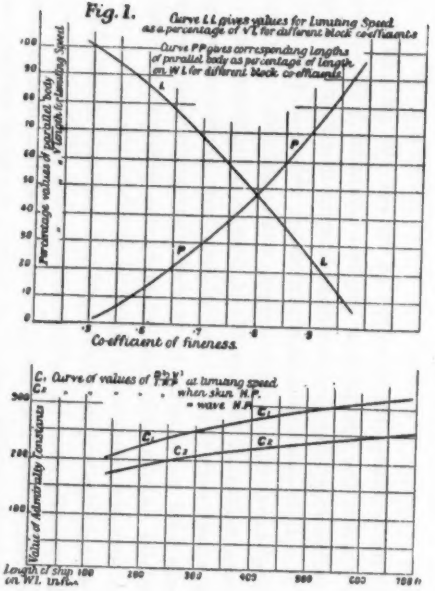


Fig. 1.
Curve LL gives values for Limiting Speed as a percentage of √L for different block coefficients
Curve PP gives corresponding Lengths of parallel body as percentage of Length on W.L. for different block coefficients
Percentage values of parallel body ÷ Length for limiting Speed
Co-efficient of fineness.
C. Curve of values of D^⅔ / H.P. at limiting speed.
C1 " " " " when skin H.P. = wave H.P.
Value of Admiralty Constants
Length of Ship on W.L. in ft.

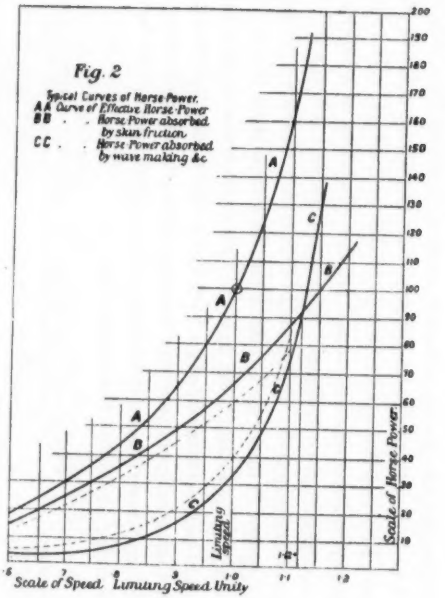


Fig. 2
Typical Curves of Horse Power.
AA Curve of Effective Horse-Power
BB " Horse Power absorbed by skin friction
CC " Horse Power absorbed by wave making &c.
Limiting speed
Scale of Horse Power
Scale of Speed. Limiting Speed Unity

seventh power of the speed; whilst the wave horsepower varies as v^7 at the limiting speed, and as v^{10}, or sometimes as a higher power of v, at 12 per cent. above the limiting speed; and that at this point, viz: about 12 per cent. above the limiting speed, the wave horsepower is approximately equal to the skin horsepower, and then rises above it, the skin horsepower, of course, always varying as $v^{2.83}$.

Figure II gives a typical curve of horsepower, *AA* being the curve of effective horsepower, with 100 as its value at the limiting or unit speed. Curve *BB* gives the skin horsepower, and curve *CC* the wave horsepower. I have not taken the curves below .6 of the limiting speed, as it is not necessary to do so for my present purpose.

The ratio of wave horsepower to skin horsepower at the limiting speed depends, of course, upon the form of entrance and run and the mean girth of the vessel up to the water line; but one-half seems to be a fair average value for vessels of fine entrance and run and full midship section. If the midship section is fined, and the wetted surface thereby reduced for the same block coefficient, it naturally follows that the entrance, or run, or both, must be filled out, with the effect that the skin resistance is reduced, and the wave making increased, bringing the curves of skin horsepower and wave horsepower more closely together, as indicated by the dotted curves on the diagram, and bringing the point where skin horsepower is equal to wave horsepower to a lower speed.

It is, therefore, impossible to lay down general rules to meet all cases, as the variations which may occur are almost infinite in number, and so only an indication of the kind of thing that may be expected can be given. Considerations of stability, involving beam, or fullness of waterline, or of girth, which affects weight of hull, more especially if the vessel is to be built to Lloyd's rules, or the question of docking facilities, are merely examples of what the designer has to take account of, and they often hamper him in adopting what he knows would be a better form, or more suitable dimensions for the speed than those he is compelled to take.

The results I have obtained are from the trials of vessels of good form for the coefficients of fineness they possess. But there are many ships whose performances are not so good as I have indicated, and there are others, again, with better performances; the latter, however, generally speaking, appear to have had rather better propulsive coefficients than the 50 per cent. I have assumed; one or two examples apparently having values of 57 to 58 per cent. The values of the Admiralty constant,

$$C = \frac{D^{\frac{2}{3}} v^3}{\text{I.H.P.}}$$

at the limiting speed, as found above, are fairly uniform, varying, however, with the size of ship as given by the table below:

Length of ship on waterline. *Feet.*	Value of C at limiting speed.	Value of C when skin H.P. = wave H.P.
200	225	188
300	256	207
400	278	224
500	295	237
600	310	246

These values of C are less for the smaller ships, on account of the higher coefficient of friction for the shorter length of vessel, and also on account of the error in the assumption of the general truth of the law of comparison when applied to the whole resistance. These two causes are not, however, sufficient of themselves to account for the decrease in the value of C. I think this decrease is partly due to eddy making, caused by minor projections and irregularities in the surface of the smaller ships, these irregularities being on a proportionately larger scale in the smaller than in the larger vessel. It must also be borne in mind that any roughness of sea or wind has a greater effect in proportion on the smaller ships, tending to spoil their performances on trial, as compared with those of larger ships.

I do not intend, when I use the term "economical" speed, to make it include the financial side of the question; as it frequently happens that it is cheaper to increase horsepower, to get a little extra speed when required, than to increase the length of the

ship, or to fine her lines. What I intend to convey is that, if a speed be aimed at slightly above the limiting speed I have defined, with the indicated horsepower increasing as more than the fourth power of the speed, it will be found possible to drive at that speed, with the same horsepower, a vessel increased in one dimension, viz: in length, and proportionally increased in displacement. Whilst, if a still higher speed be aimed at, the vessel may be increased in two dimensions, viz: length and draught, or length and beam, and still attain the higher speed, with the same horsepower as the smaller ship. Finally, as was proved by the late Mr. Froude, when the indicated horsepower is increasing as the seventh power of the speed, it is possible to drive a similar ship, increased in all three dimensions, at the same speed, with the same horsepower as the smaller vessel, and this is more than borne out by the facts.

I have shown that the indicated horsepower is usually increasing at this rate, viz: as v^7, when skin horsepower = wave horsepower, or at about 12 per cent. above the limiting speed. This is then the speed at which it becomes economical to increase all the dimensions of the ship in the same proportion; of course, from the point of view of driving the greatest displacement at the given speed.

There are many vessels in which this limiting speed is far exceeded, such as fast cross-channel passenger vessels, torpedo gunboats and destroyers; but these types are for very special requirements, and are not economical in the sense of carrying large displacement at the required speed. They are not, therefore, included in the scope of this paper. Nor do the figures I have given apply to vessels of very great beam in proportion to their length. The examples I have taken are all of ordinary proportions, not less than $6\frac{1}{2}$ beams in length, and of ordinary draughts; but, as this includes practically all mercantile vessels, and also cruisers of the usual dimensions, the range is fairly wide.

In these two latter classes the number of indicated horsepower per ton of displacement rarely exceeds two. In the slower vessels of the mercantile marine it goes as low as $\frac{1}{4}$ in-

dicated horsepower per ton of displacement. In the torpedo-boat destroyers it goes as high as 20, and in H. M. S. *Viper*, with the turbine machinery, has, I understand, reached about 30. So that the exclusion of these very fast craft from a paper dealing with the economical side of the speed and horsepower problem is obviously reasonable. The very broad vessels, also to some extent abnormal, have, therefore, been excluded, as have also the performances of paddle boats.

As regards the comparative performances of single and twin-screw vessels, there appears to be little difference in vessels of good form.

Reverting to the limiting economical speed as defined, I find that, generally, for 1 per cent. increase above this limit of speed, 5 per cent. increase of horsepower is necessary; and at the speed when skin horsepower = wave horsepower, or about 12 per cent. above the limiting speed, 1 per cent. increase of speed requires 10 per cent. increase of power. Taking these figures, it appears to me that any increase of speed above the limits indicated should be most carefully weighed before adopting it, in view of the disproportionate increase in power and weight of machinery thereby rendered necessary, together with increased engine-room staff, the larger coal bill, and the reduced weight and capacity for cargo. I think there are ships that might well have been made finer, or have had their speed and power reduced when in the design stage, at the cost of foregoing that last half knot, which possibly requires from 20 to 25 per cent. additional horsepower, enabling the vessel, perhaps, to steam a distance of 12 knots farther in 24 hours at the cost of burning out coal which would keep her a whole extra day at sea at half a knot less speed, and this without taking into account the original saving in weight and cost of machinery which might have been made.

In conclusion, I would say that I have had great difficulty in obtaining reliable data of progressive trials of ships with very large coefficients of fineness. In these vessels, usually, no progressive trials are made, and, in any trial that does take place, frequently the propellers are only partially submerged.

THE EDISON STORAGE BATTERY.

By Dr. A. E. Kennelly.

[Paper read at the annual meeting of the American Institute of Electrical Engineers.]

It is well known that the history of the storage cell is essentially that of the lead cell discovered by Planté in 1860, in which lead peroxide is the depolarizing substance. An enormous amount of labor has, in the aggregate, been expended upon the improvement of this cell in the hands of experimentalists. As a result of that labor, the storage battery has at last become a recognized adjunct to direct-current central stations, but it has limitations that seem to withstand further attempts toward improvement. Of recent years, hardly any success has been met with in the direction of reducing its weight for a given energy storage capacity, without detriment to endurance, and this weight is the great drawback of the storage battery in electric storage traction, and has been the principal obstacle to its advance in this direction for the past twenty years.

In practice, the storage energy per unit mass of the modern lead battery is from 4 to 6 watt-hours per pound of battery (8.8 to 13.23 watt hours per kilogram). Expressed in another way, a battery weighs from 124.5 to 186.5 pounds per horsepower-hour at its terminals (75.5 to 113.4 kilograms per kilowatt-hour); or if its stored energy available at terminals were all expended in gravitational work a battery could raise its own weight through a vertical distance of from 2 to 3 miles (3.2 to 4.8 kilometers).

While it is possible to increase the energy per unit mass by making the electrodes very light, yet this is always found to be followed by a very heavy deterioration.

OBJECTS SOUGHT.

Mr. Edison set himself the task of finding a cell which should possess the following advantages:

1. Absence of deterioration by work.
2. Large storage capacity per unit of mass.
3. Capability of being rapidly charged and discharged.
4. Capability of withstanding careless treatment.
5. Inexpensiveness.

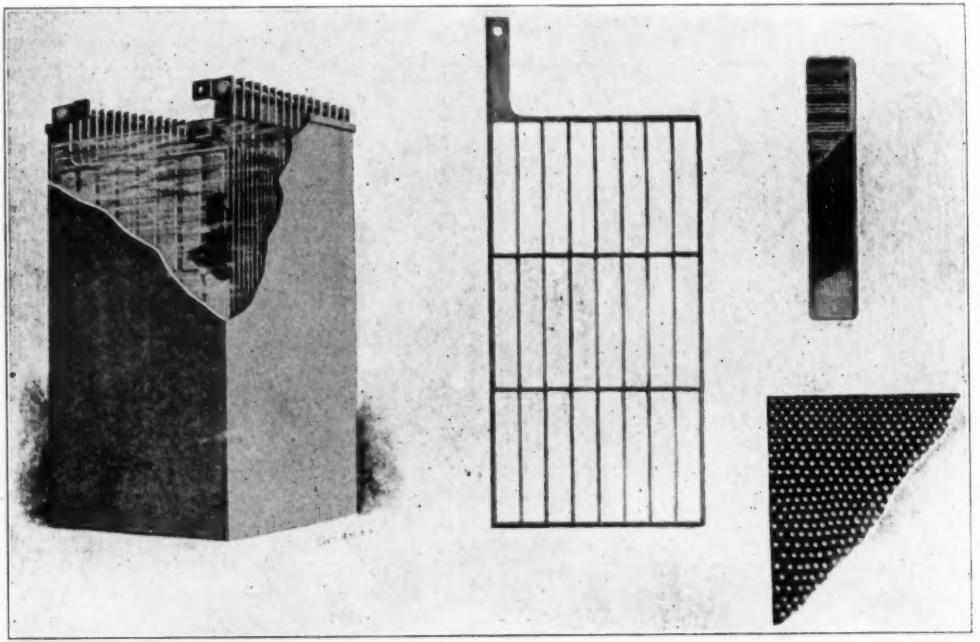
He believes that the cell here shown may claim these advantages in a very satisfactory degree.

ELEMENTS OF BATTERY.

The negative pole or positive element, corresponding to the zinc of a primary cell or the spongy lead of a secondary cell, is iron. The positive pole or negative element, corresponding to the carbon of a primary cell or lead peroxide of a secondary cell, is a superoxide of nickel believed to have the formula NiO_2. The cell is therefore a nickel-iron cell, a name which suggests the structural material nickel-steel. The electrolyte is potash—viz: an aqueous solution containing from 10 to 40 per cent. by weight, but preferably 20 per cent., of potassium hydroxide, the freezing temperature of which is 20° degrees below zero Fahrenheit, or 30 degrees centigrade.

CAPACITY.

The initial voltage of discharge after recent charge is 1.5 volts. The mean voltage of full discharge is approximately 1.1 volts. The normal discharging current rate per unit of active element (positive or negative) is 60 $\frac{\text{milliampères}}{\text{square inch}}$ or 8.64 $\frac{\text{ampères}}{\text{square foot}}$ or 0.93 $\frac{\text{ampères}}{\text{square decimeter}}$. The storage capacity of the cell per unit of total mass of the cell is 14 watt-hours per pound, or 30.85 watt-hours per kilogram. Expressing the same statement in another way, the weight of battery per unit of electric energy at terminals is 53.3 pounds per electrical horsepower-hour or 32.4 kilograms per kilowatt-hour. Or the battery gives energy



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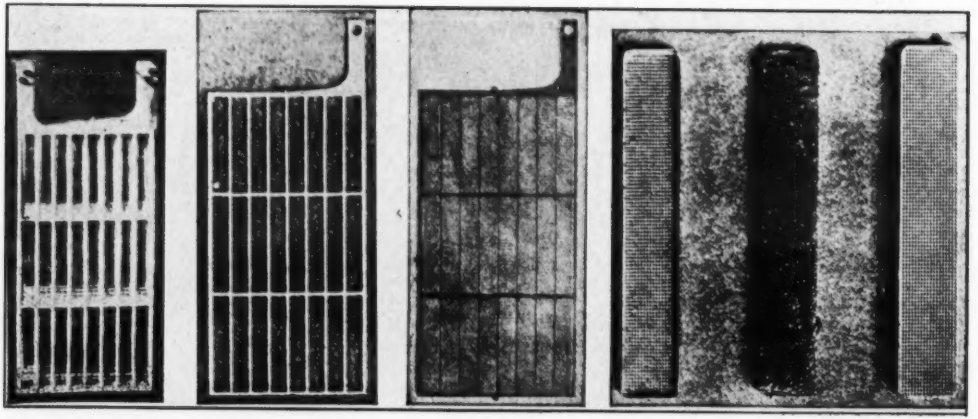

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at its terminals sufficient to lift its own weight through a vertical distance of approximately 7 miles, or 11.26 kilometers. The mean normal discharging power rate per unit mass of total cell is 4 watts per pound, or 8.82 watts per kilogram, corresponding to a normal discharge period of 3½ hours. The cell may, however, be discharged at a relatively high rate, in approximately one hour, corresponding to a discharging power rate per unit of total cell mass of 12 watts per pound, or 26.46 watts per kilogram. Charging and discharging rates are alike. That is to say, the cell may be charged at the normal rate in 3½ hours, or it may be charged at a relatively high rate in 1 hour, with no apparent detriment beyond a somewhat lowered electrical charge efficiency. In other words, the cell does not appear to be injured by overcharging or discharging, and only suffers in electrical efficiency under such treatment.

CONSTRUCTION OF PLATES.

The positive and negative plates are mechanically alike, and can scarcely be distinguished by the eye. They differ only in the chemical contents of their pockets. Each plate is formed of a comparatively thin sheet of steel, 0.024 inch (0.61 millimeter) in thickness, out of which rectangular holes are stamped, so as to leave a grid or frame somewhat resembling a window frame. In the plate here shown there are three rows of eight such rectangular holes or recesses, or 24 recesses in all.

Each opening or recess is filled with a pocket or shallow box containing the active material. These boxes correspond to the panes of glass in the window frame analogy. The panes, instead of being thinner than the frame, as in an actual window, are thicker than the frame, or project slightly beyond the surface of the steel grid. They are perforated with numerous small holes to admit the electrolyte, but entirely conceal the contained active material from view. All that meets the eye, therefore, in any of the plates is the steel frame and its imbedded "windows" of perforated steel.

The active material is made in the form of rectangular cakes or briquettes, and one such briquette is lodged in each pocket or

"window pane" of the plate. Each of the plates shown, therefore, supports, or contains, 24 briquettes of active material, all in rigid contact with its own substance.

Each briquette is placed in a shallow, closely-fitting nickel-plated box of thin, perforated crucible steel, cut from a long strip of that material 0.003 inch (0.075 millimeter) thick. A cover or lid of the same material is then laid over it, so that the briquette is closely enveloped by the sides and walls of its perforated steel box. The boxes are then placed in the openings or holes in the nickel-plated steel grid, and closely fit the same. The assembled plate is then placed in a hydraulic press and subjected to a total pressure of about 100 tons. This pressure not only tightly closes the boxes, but it also forces their metal sides over the adjacent sides of the recesses in the steel grid, thus clamping the whole mass into a single, solid and rigid steel plate with the hollow "window panes" full of active material. The nickel plating of both grids and boxes aids in securing good permanent electric connections between them. The finished plate has a grid thickness of 0.024 inch (0.56 millimeter) and a window or pocket thickness of 0.1 inch (2.5 millimeter). This is the maximum thickness of the plate at any point, but being of steel, the plate has ample rigidity.

The positive briquettes (zincs of a primary cell) are made by mixing a finely-divided compound of iron obtained by a special chemical process with a nearly equal volume of thin flakes of graphite. The graphite does not enter into any of the chemical actions, but assists the conductivity of the briquettes. The graphite is divided into very thin laminæ by a chemical process, and these are passed through sieves or screens so as to leave a size or area of flake that is much larger than the area of the perforation in the steel windows. The mixture is then pressed into briquettes in a mold, under a hydraulic pressure of about 2 tons per square inch. The briquettes have a surface area of nearly 3 inches by $\frac{1}{2}$ inch on each face.

The negative briquette (carbon of a primary cell) is made by similarly mixing a finely-divided compound of nickel, obtained by special chemical means, with a nearly equal bulk of fine flakes

of graphite, and solidifying the mixture in a mold into briquettes of the same size as above.

A suitable number of positive and negative plates are assembled together, being separated from one another only by a thin sheet of perforated hard rubber.

The assembled plates are placed in a vessel or external containing cell of sheet steel containing the potash solution, which, of course, does not attack steel. There was, however, much difficulty from the action of the potash on the soldered seams of the steel containing vessel. After many trials, however, Mr. Edison found a solder which seems to be entirely unaffected by the alkali.

CHEMICAL ACTION.

In charging, the current is, of course, sent into the positive pole and its attached negative nickel plate through the electrolyte, and into the positive plate of the iron compound which carries the negative pole. This current deoxidizes or reduces the compound to a spongy metallic iron and carries the oxygen through the film of electrolyte to the nickel compound, oxidizing it to the hyperoxide of nickel, NiO_2, a higher oxide than the peroxide. In other words, the charging current simply carries oxygen in the opposite direction against the forces of chemical affinity, from the iron to the nickel, and stores the energy in the reduced iron, which is, of course, unaffected and passive in the presence of the potash solution. On discharge, the current passes from the positive pole through the external circuit to the negative pole, and its attached iron or positive plate, and then through the solution to the negative or superoxide plate. In so doing the oxygen moves back against the current and partially reduces the nickel superoxide NiO_2 while oxidizing the spongy iron. The energy of burning of the iron and oxygen which would be developed as heat in the ordinary chemical process is now liberated in the circuit as electrical energy.

The cell is an oxygen lift. Charging pulls the oxygen away from the iron and delivers it temporarily to the nickel. The condition is then stable until the circuit of the cell is completed.

Discharge then allows the oxygen to fall back from the nickel to the iron with the natural affinity of iron and oxygen.

This action is very different from that which takes place in the lead storage cell. Here, neglecting complications, the action is usually regarded for practical purposes as being represented by the equation

$$PbO_2 + 2H_2SO_4 + Pb = 2FbSO_4 + 2H_2O + 100 \text{ watt-hours},$$

where the left-hand side represents the condition of charge and the right-hand side the condition of discharge. Here oxygen is not simply transferred in discharge from the peroxide to the spongy lead, but the solution is changed (theoretically) from an aqueous solution of sulphuric acid to plain water. Of course, the dicharge could not practically be carried to the point of denuding the solution of all sulphuric acid, and a surplusage of acid must be used. The equation gives a mere theoretical outline of admittedly very complex reactions. In other words, the specific gravity of the sulphuric acid solution falls during the discharge, and the solution enters into the chemical combination. Theoretically, for every 445 grammes of active material on both plates, 196 grammes of sulphuric acid are required to effect the combination, or 44 per cent. by weight of the active elements, and in practice it is usual to allow a weight of sulphuric acid nearly equal to half the weight of the elements, or about one-quarter of the total weight of the cell.

In the new Edison cell, on the other hand, the theoretical action of the potash solution is merely to provide the proper channel through which the oxygen ions may travel in one direction or the other—positive plate to negative plate in charge, and negative plate to positive plate in discharge. Consequently, the amount of solution needs only to be sufficient to fulfill mechanical requirements. It is believed that the weight of solution will in practice be only about 20 per cent. of the plate weight or about 14 per cent. of the cell weight. In fact, the cell may be worked in the same manner as the so-called primary "dry-cells." Moreover, if the solution should escape, or be carried away, by gasing in charging, the only detriment seems to be the loss of

active surface thereby occasioned, and it will only be necessary to fill up the cells to the proper level with water from time to time, as evaporation or gasing may lower the level. For the same reasons the specific gravity of the electrolyte does not appreciably vary during charge and discharge.

The briquettes of active material slightly expand on receiving oxygen and slightly contract on delivering it, that is to say, the iron briquettes contract and the nickel briquettes expand during charge, while on discharge the iron briquettes expand and the nickel briquettes contract. The level of the solution is in this way scarcely affected. The expansions and contractions of the briquettes appear to be well within the elastic limits of the spring-steel containing boxes, and consequently the electric contact is always secure. The covers or sides of the window pockets merely approach to or recede from each other slightly during charge and discharge. Fortunately, steel is the metal which possesses this mechanical elasticity in a marked degree.

The action of the charging and discharging current upon the briquettes seems to be transferred from their external surfaces inwards in a manner similar to the transfer of carbon and oxygen in the process of making malleable cast iron in the furnace on the principle of cementation. No active material has been found to be ejected from the briquettes through the window perforations, even under the deliberate overcharging and discharging. Such gas as is thereby produced makes its appearance on the external surface of the windows.

If the nickel compound had no affinity for oxygen, so that energy was neither developed nor absorbed in the deoxidation or further oxidation of that substance, then the energy would be entirely that due to the energy of combination of oxygen and iron, stated to be 79.7 watt-hours, and representing an e. m. f., theoretically obtainable, of 1.47 volts. If the combination of oxygen with the nickel compound be exothermic or energy releasing, then the watt-hours delivered (and the e. m. f.) will be lessened by the energy necessarily paid back to break up the combination.

If, on the other hand, the combination is endothermic or

energy-absorbing, then the watt-hours delivered (and the e. m. f.) will be increased by the energy restored on breaking up the combination. Since the superoxide seems not to have been known hitherto, no information concerning its energy of combination is obtainable. The e. m. f. of the cell seems to be so near to that of the union of iron and oxygen as to suggest that the nickel superoxide is not far from being neutral, or that the nickel compound has but little affinity for oxygen, although the superoxide appears to be quite stable in the cell.

The new cell does not seem to be appreciably influenced by changes of temperature, and should stand a very low temperature without detriment. The electrolyte—potash—does not attack any of the ingredients of the cell, nor are any of the ingredients soluble therein. No local action occurs in the cell so far as has yet been observed, since the e. m. f. is below that necessary to decompose water.

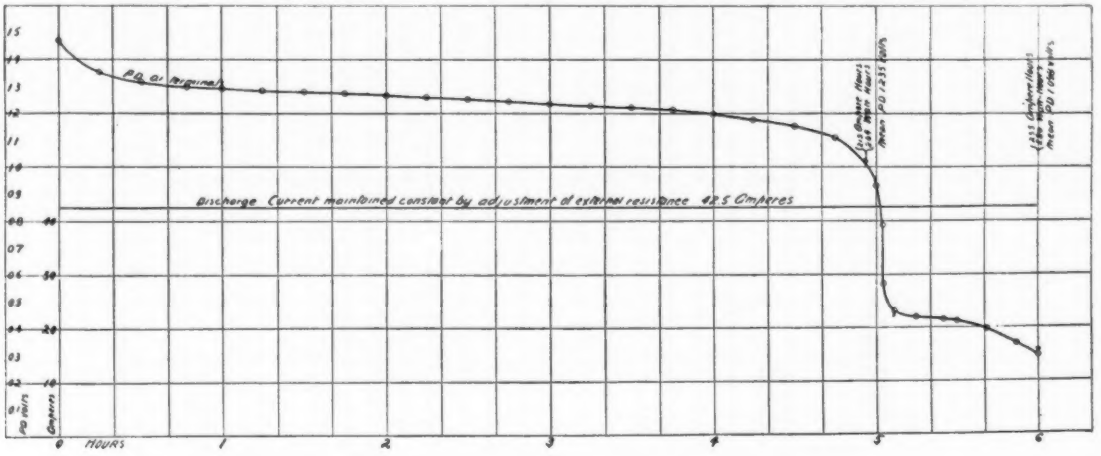
The cell may be fully discharged to the practical zero point of e. m. f. without detriment. In fact, a cell has not only been completely discharged, but recharged in the reverse or wrong direction, and after bringing it back to its originally charged state by proper restoration of the direction of charging current, the storage capacity remained unaffected. It would seem, therefore, that the cell should be capable of withstanding much abuse.

Diagrams are shown giving the curves of discharge of experimental cells.

Mr. Edison states that the negative plate (nickel), either charged or discharged, can be removed from a working cell, and dried in the air for a week, without appreciably injuring it, and when the plate is finally replaced in the cell its charge is practically undiminished.

The positive (iron) plate, if similarly removed from the cell, will be likewise uninjured, but it soon loses its charge by the oxidation of the spongy iron with accompanying liberation of heat and appreciable rise of temperature extending over a period of several hours. On replacing the electrode, however, in the cell the storage capacity is unaffected on recharge.

As regards cost, Mr. Edison believes that after factory facilities


15
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1.233 Ampere Hours
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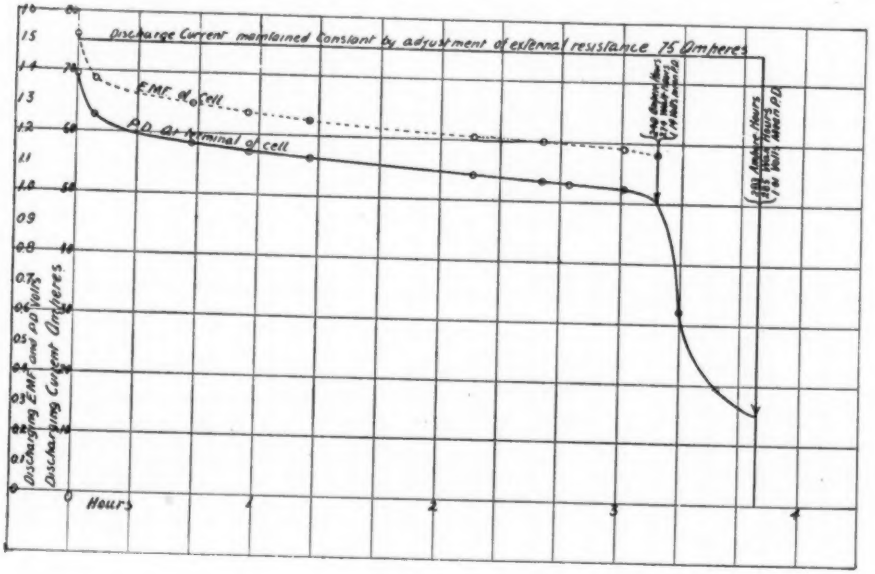
Meter P.D. 1.086 Volts


Discharge Current maintained constant by adjustment of external resistance 75 Amperes
E.M.F. of Cell
P.D. at terminal of cell
Discharging E.M.F. and P.D. Volts
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0
1
2
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4

now in course of preparation have been completed, he will be able to furnish the cells at a price per kilowatt-hour not greater than the prevailing price of lead cells.

Having now considered the action and properties of the cell, a brief description may be given of the difficulties encountered in developing it.

The phenomenon of passivity has probably kept inventors from finding this cell in the past. Mr. Edison believes that of all the very numerous compounds of iron, and of which he has tried many hundreds, the particular compound which he prepares is perhaps the only one capable of being used in this way.

If the dried hydrates, or oxides of iron, native or artificial, are subjected to electrolytic reducing action in any alkaline solution, they remain inert and unaffected.

On the other hand, if finely divided iron obtained by reducing a compound of iron under the action of a reducing agent, such as hydrogen or carbon monoxide, is subjected to electrolytic oxidation in an alkaline solution, it is inert and cannot be oxidized. It assumes the well-known passive state.

The same difficulty of passivity affects the use of nickel or the negative element. Finely-divided nickel, reduced from a nickel compound, remains inactive when subjected to electrolytic oxygen in an alkaline solution. The monoxide and the black oxide or peroxide are also inert. No oxide of nickel is active or can be made active by electrolytic action, and the peroxide does not act as a depolarizer.

THE INFLUENCE OF COPPER ON STEEL RAILS AND PLATES.

By J. E. Stead and John Evans.

[Paper read before the Iron and Steel Institute.]

The effect of copper in iron and steel is not well known, although much has been written on the subject. It is, however, generally believed, in this country, at least, that it has a very deleterious effect. So strong is this prejudice that engineers and others frequently, when buying steel or the material from which it is manufactured, specify that copper must be practically absent. As the facts scarcely justify such practice, it appeared to us desirable to draw the attention of the Iron and Steel Institute to the subject.

HISTORICAL.

One of us has recently given a brief summary of the evidence contained in text books and elsewhere as to the effect of copper in iron and steel; it is, therefore, not proposed in this note to refer to any but the most important results of previous work in which analyses and mechanical properties are correlated.

Dr. Edwin J. Ball and Mr. Arthur Wingham studied the influence of copper on the tensile strength of cast steel. The alloys were made in crucibles, and when melted were allowed to cool in them. Test pieces 1 inch by $\frac{1}{4}$ inch by $\frac{3}{16}$ inch were cut from the solid metal, and after annealing they were submitted to tensile tests.

In addition to these tests forging tests were made. No. 4 forged well in the cold, but was redshort. In concluding their paper, Dr. Ball and Mr. Wingham state that within certain limits copper does not prejudicially affect the mechanical properties of steel, but point out that the experiments were of necessity conducted on a small scale. They presented the results with some diffidence.

The results of these are given in the following table.

Test pieces, number.	Copper.	Carbon.	Tensile strength per square inch.
	per cent.	*per cent.*	*tons.*
Original steel	...	0.133	29.0
1	0.847	0.102	18.3
2	2.124	0.217	36.6
3	3.630	0.380	47.6
4	7.171	0.712	56.0
5	4.10	0.183	43.2
6	4.44	trace.	34.3

Mr. H. H. Campbell has proved by a large number of experiments that 0.25 per cent. copper has no effect upon the mechanical properties of the steel, excepting that of slightly raising its elastic limit. If anything, the copper steels show greater ductility than steels with less copper. He presents the table in the next column.

Campbell, in commenting on these results, says: "It will be noted that no difference is to be found in the ultimate strength between steels with high and low copper, although all the heats were made in the same way as nearly as possible, the workmen not knowing, either in the Bessemer department or in the rolling mill, what kind of iron was in use. Moreover, the high copper gives a slightly higher elastic ratio, which is a benefit, and also a better elongation and reduction of area."

COMPARATIVE PHYSICAL PROPERTIES OF LOW-COPPER AND HIGH-COPPER STEEL ANGLES.

Thickness in inches.	Copper.	Number of heats.	Ultimate strength per sqr. inch.	Elastic limit per sqr. inch.	Elongation in 8 ins.	Reduction of area.	Elastic ratio.
	per cent.		*pounds.*	*pounds.*	*per cent.*	*per cent.*	*per cent.*
$\frac{5}{16}$	0.10	11	61,376	44,152	27.52	56.30	71.9
	0.35	17	60,283	43,841	27.88	59.01	72.7
$\frac{3}{8}$	0.10	10	58,965	42,218	28.85	55.50	71.6
	0.35	11	59,630	43,478	29.02	57.86	72.9

Professor J. O. Arnold appears to have had no difficulty in hammering an ingot with 0.1 per cent. carbon and 1.8 per cent. copper. The following mechanical tests made by him of pure iron and iron alloyed with 1.29 per cent. manganese are here

given for comparison with the steel alloyed with 1.8 per cent. copper, viz:

—	Pure iron.	Manganese 1.29 per cent.	Copper-steel.
Elastic limit, tons	14.39	22.72	30.8
Tensile strength, tons	21.77	32.16	34.8
Elongation, per cent	47	35	30.5
Reduction of area, per cent	76.50	65	62.2
Carbon, per cent	0.04	0.10	0.10
Manganese, per cent	...	1.29	...
Copper, per cent	...	...	1.81

These results lead to the conclusion that the effect on the mechanical properties of manganese and copper, within certain limits, are comparable. Had the manganese been 1.8 per cent. instead of 1.29 per cent., probably the mechanical properties would have most closely agreed as regards the tenacity, elongation, and reduction of area. The great difference between the effect of manganese and copper appears to be that copper has greater influence than manganese in raising the elastic limit.

Mr. T. W. Hogg found that copper does not tend to segregate in steel. In the center of a large ingot, where the phosphorus and carbon had greatly segregated, the copper existed in practically the same amount as it did near the outside. The analytical results were as follows:

—	Inside of ingot.	Near the outside of the ingot.
	per cent.	*per cent.*
Carbon	0.75	0.20
Sulphur	0.15	0.036
Phosphorus	0.20	0.042
Copper	0.054	0.052

Mr. Albert Ladd Colby, South Bethlehem, Pennsylvania, in a most exhaustive investigation on the effect of copper in steel shafts, gun tubes, on ship and boiler plates, Bessemer steel rails, &c., has proved that steel may contain considerable quantities of copper without disadvantage. He did not find that 0.56 per cent. copper made steel redshort, and the mechanical properties, when cold, were quite satisfactory. The following analyses and mechanical tests of such steel are selected as examples:

GUN STEEL.

	Per cent.
Copper,	0.553
Carbon,	0.390
Manganese,	0.700
Silicon,	0.182
Phosphorus,	0.057
Sulphur,	0.055

Number of specimens tested.	Tensile strength per square inch.	Elastic limit per square inch.	Elongation in 2 inches.	Contraction of area.
	tons.	*tons.*	*per cent.*	*per cent.*
Average.....	29.25	17.16	31.12	51.92

CRANK-SHAFT STEEL.

	Per cent.
Copper,	0.565
Carbon,	0.250
Manganese,	0.640
Silicon,	0.149
Phosphorus,	0.047
Sulphur,	0.034

Number of specimens tested.	Tensile strength per square inch.	Elastic limit per square inch.	Elongation in 2 inches.	Contraction of area.
	tons.	*tons.*	*per cent.*	*per cent.*
Average.....	35.11	20.64	24.92	44.67

The welding and flanging properties of open-hearth steel containing 0.575 per cent. copper and 0.138 per cent. carbon were most satisfactory, and Mr. Colby naturally points out the needlessness of limiting the copper in boiler fire boxes and structural steel to 0.050 per cent. or 0.100 per cent.

Mr. W. Lipin practically confirmed Mr. Colby's work, but extended his researches much beyond the limits of 0.60 per cent. copper. This author found that iron containing up to 3 per cent. copper could be readily worked. Redshortness became evident when it reached 4.7 per cent., and when from 7 to 10 per cent. was present it cracked badly and fell to pieces under the hammer. The following analyses and mechanical tests are given:

	Original Iron.	Cupreous Steel.
Carbon, per cent.,	0.10	0.13
Manganese, per cent.,	0.14	0.30
Silicon, per cent.,	0.09	0.14
Sulphur, per cent.,	0.334	0.009
Phosphorus, per cent.,	0 023	0.023
Copper, per cent.,	Nil.	3.200
Tensile strength, tons per sq. inch,	26	46.5
Elastic limit, tons per sq. inch,	...	38.17
Elongation, per cent.,	27.8	13.3

It is shown that as the carbon is increased the copper must be reduced, and that if the carbon is 0.43 per cent. the copper must not exceed 2 per cent. If it exceeds that limit, redshortness becomes evident. The same author has shown that as much as 1 per cent. copper may be present in tool steel, but as the hardening effect of copper is so energetic, the quenching of the heated steel must be done in oil rather than in water. It is also stated that copper did not have any deleterious effect on weld iron or in the puddling process.

The evidence given in the careful researches above referred to is not exhaustive and convincing. When it is also remembered that steel rails with above 0.3 per cent. copper have been used in America for many years without any disadvantage, and that M. Henri Schneider, of Le Creusot Works, actually patented a process of adding copper to steel, and claimed that steels alloyed with copper are useful in the manufacture of armor plates, gun barrels, projectiles, etc., it appeared to be scarcely necessary to make further research.

Mr. A. Ruhfus, however, in discussing Mr. Lipin's investigations, disputes the conclusion that redshortness is not brought about till the copper exceeds 2 or 3 per cent., but admits that 0.4 per cent. copper may be present in ingot iron without making it redshort, and that in steel for welding it should not exceed 0.3 per cent. He endeavored to explain the difference between his results and those of Mr. Lipin by showing that the latter made his experimental steel charges in crucibles which were not so liable to be affected by oxidation as his own made on a larger scale.

The results obtained by Mr. Colby appear to be a sufficient answer to Mr. Ruhfus's contention, at least for steel made on a large scale with about 0.6 per cent. copper. As, however, Mr. Colby had not experimented with more than the amount referred to, it appeared desirable that further practical trials should be made with steels containing between 0.5 and 2 per cent. copper to ascertain at what point copper does become harmful. We have, therefore, made several charges of cupreous steel and tested them mechanically.

REPORT ON EXPERIMENTS MADE AT ESTON.

The experiments were made at the works of Messrs. Bolckow, Vaughan & Co., Limited, Middlesbrough, and every facility was given us by Mr. David Evans, the general manager, to obtain practical results. To him and to his agents our thanks are due for valuable co-operation and assistance.

The system adopted was the same as that previously used by one of us in determining the effect of arsenic on steel. In each trial the fluid charge of the liquid steel in the ladle was divided into two parts, to one of which was added the element the effect of which it was sought to determine. Both parts were then cast into the same size ingots. By this means strictly comparable results were obtained, the two parts differing only in the element added. The rolling was carefully watched, the steels were marked, and when cold were carefully tested. Four series of Bessemer rail steels were made, containing respectively about 0.5, 0.9, 1.3, and 2 per cent. copper. One open-hearth charge was also experimented upon, to which 0.5 per cent. copper was added. In all cases the cold copper ingots, when thrown into the liquid steel, readily melted and mixed most perfectly with it. In no case did it deaden or make the steel more lively in the molds.

In every parallel case the steels containing copper rolled as perfectly as those without it, with the exception of the rail steel containing about 2 per cent. copper, which was torn on the flanges. An examination of the finished rails (2 per cent. copper) showed that this defect was caused by overheating; the

heads, however, were perfect, and after being slotted off were reheated and rolled into wire rod without cracking or breaking up in the least degree. The forgemen and rollers were of the opinion that the steel could be easily worked, and was good, sound material. The companion ingots without the copper under the same heat treatment were not overheated. We conclude from this that steel with very large percentages of copper, although not redshort in the ordinary sense, will not bear the same amount of heat as when copper is absent, and that its effect in this respect resembles that of carbon and not that of sulphur.

A remarkable result was obtained in the trial with open-hearth steel in which 0.5 per cent. copper was added. In rolling the non-cupreous part every ingot cracked perceptibly, whereas, the same steel containing the copper rolled without a flaw. It is difficult to believe that copper will prevent redshortness, but this result would certainly lead to the belief that it does so.

CHEMICAL ANALYSES OF BESSEMER RAILS.

—	Carbon.	Manganese.	Silicon.	Sulphur.	Phosphorus.	Copper.
Series I:	*per cent.*	*per cent.*	*per cent.*	*per cent.*	*per cent.*	*per cent.*
Cupreous	0.42	0.93	0.065	0.030	0.067	0.480
Normal	0.43	0.94	0.065	0.030	0.063	0.025
Series II:						
Cupreous	0.49	0.933	0.075	0.047	0.082	0.889
Normal	0.480	0.933	0.070	0.047	0.084	0.033
Series III:						
Cupreous	0.320	0.640	0.028	0.055	0.048	1.286
Normal	0.330	1.090	0.028	0.118	0.049	0.012
Series IV:						
Cupreous	0.290	0.676	0.084	0.044	0.082	2.000
Normal	0.310	0.676	0.084	0.047	0.084	0.012

The analyses were made on drillings taken from the rails after they had been tested mechanically.

In series No. 3 it will be observed that the manganese in the normal sample is much higher than that in the cupreous steel; the sulphur and phosphorus are also different, from which we

must conclude that an ingot from another charge was rolled by mistake, and therefore the comparison cannot be exact.

Behavior of Steels During Rolling.

Series I (Cu. 0.48)..... Both steels rolled equally well.
" II (Cu. 0.889)..... Ditto.
" III (Cu. 1.286)... Ditto.
" IV (Cu. 2.000)..... The cupreous rail burst in the flanges during rolling, but it was proved that the material had been overheated. The heads were not flawed. After sawing them off they were reheated and rolled to wire rod without a flaw.

PERCUSSIVE TESTS.

The rails in series I, II and III were of bull-head section, and weighed 90 pounds per yard. Those in No. IV series were flanged rails, and weighed 56 pounds per yard.

In applying the percussive tests, pieces of the rails 5 feet in length were placed on bearings 3 feet 6 inches apart; a weight of 1 ton was allowed to fall on the heads from a height of 20 feet in the cases of series I to III, and 15 feet in series IV. After the first blow the weight was allowed to fall a second time from the same height. The deflection produced was noticed after each blow:

		Deflections in Inches.	
		First blow.	Second blow.
Series I.....	Cupreous.....	$3\frac{1}{4}$ $3\frac{1}{16}$	$5\frac{1}{16}$ $5\frac{7}{8}$
	Normal.....	$3\frac{5}{32}$ $3\frac{3}{16}$	$5\frac{3}{32}$ $5\frac{7}{8}$
Series II.....	Cupreous.....	$3\frac{1}{8}$ $3\frac{1}{4}$	$5\frac{3}{4}$ $6\frac{1}{16}$
	Normal.....	$3\frac{3}{8}$ $3\frac{1}{2}$	$6\frac{1}{8}$ $6\frac{3}{8}$
Series III.....	Cupreous.....	$3\frac{1}{16}$ $3\frac{1}{16}$	$5\frac{1}{16}$ $5\frac{3}{4}$
	Normal.....	$3\frac{1}{16}$ $3\frac{1}{4}$	$5\frac{3}{4}$ 6
Series IV.....	Cupreous.....	$4\frac{7}{16}$ $4\frac{7}{16}$	broke. 11
	Normal.....	$5\frac{7}{8}$ $6\frac{1}{16}$	$12\frac{1}{8}$ $12\frac{3}{8}$

The cupreous rails in No. IV series had flaws in the flanges caused by overheating, and in consequence a second blow broke them, fracture starting from the flaws. Had the rails been sound, in all probability they would not have been broken. All the other cupreous rails stood the very severe test without breaking.

TENSILE TESTS.

Portions of the rails were cut up, and test pieces were turned into shape for testing by tension. The following results were obtained:

SERIES NO. 1.—COPPER, 0.60 PER CENT.

—	Cupreous.			Normal.		
	Large head.	Small head.	Web.	Large head.	Small head.	Web.
Breaking weight, tons per square inch	45.9	46.05	48.3	43.9	44.85	45.15
Elastic limit, tons per square inch	25	...	...	25.2	...	...
Elongation in 2 inches, per cent	18	21	19	19	20.50	22.5
Contraction of area, per cent	12.75	25.6	26.8	21.2	25.60	35.9

AVERAGE RESULTS.

—	Cupreous.	Normal.	Effect of Copper.
Breaking weight, tons per square inch	46.55	44.63	+ 1.92
Elastic limit, tons per square inch	25	25.20	— 0.20
Elongation in 2 inches, per cent	19.30	20.66	— 1.36
Contraction of area, per cent	21.38	27.56	— 6.18
Series No. II.—Copper, 0.889 Per Cent.			
Breaking weight, tons per square inch	49.4	48	+ 1.4
Elastic limit, tons per square inch	27.1	24.8	+ 2.3
Elongation in 2 inches, per cent	23	21	— 2
Contraction of area, per cent	37	32	+ 5
Series No. III.—Copper, 1.286 Per Cent.			
Breaking weight, tons per square inch	42.2	41.6	+ 0.6
Elastic limit, tons per square inch	28	23.4	+ 4.6
Elongation in 2 inches, per cent	23	26	— 3
Contraction of area, per cent	35	39.5	— 4.5
Not strictly comparable. (See analyses.)			
Unannealed Rail Heads.—Series No. IV.—Copper 2.00 Per Cent.			
Breaking weight, tons per square inch	49.7	39.7	+ 10
Elastic limit, tons per square inch	35.9	22.1	+ 13.8
Elongation in 2 inches, per cent	21.5	27	— 6.5
Contraction of area, per cent	35.4	41	— 5.6

ANNEALED RAILS.

—	Cupreous.		Normal.	
	Large head.	Web.	Large head.	Web.
Breaking weight, tons per square inch..	43.9	51.1- 5.05	39.6	44
Elongation in 2 inches, per cent.....	23	17 -16	24	25
Contraction of area, per cent.....	32	37.1-42.4	36.3	46.30

AVERAGE RESULTS.

—	Cupreous.	Normal.	Effect of copper.
Breaking weight, tons per square inch.....	47.35	41.80	+ 5.55
Elongation in 2 inches, per cent.....	19.75	24.50	— 4.85
Contraction of area, per cent.....	35.87	41.30	— 5.43

The elastic limit was taken by dividers in every case.

OPEN-HEARTH STEEL.

A single charge of acid open-hearth steel was experimented upon in the same manner as those from the Bessemer converter. It was divided into two parts, when fluid and copper ingots were added to one part sufficient to yield 0.46 per cent. copper.

The following are the analyses of the steels made:

CHEMICAL ANALYSIS.

	Cupreous. Per Cent.	Normal. Per Cent.
Carbon, ...	0.310	0.320
Manganese, ...	0.614	0.614
Silicon, ...	0.028	0.030
Sulphur, ...	0.090	0.090
Phosphorus, ...	0.069	0.069
Copper, ...	0.460	0.021

BEHAVIOR OF THE STEELS AT THE ROLLS.

Both parts were rolled into $\frac{1}{2}$-inch plates.

When cogging down, the normal steel cracked, and appeared to be slightly redshort, whereas, as before stated, the cupreous

steel passed the rolling mills without showing the slightest red-shortness.

TENSILE AND BENDING TESTS.

Samples taken from various parts of the cupreous plates on analysis were proved to be homogeneous. The copper did not vary more than 0.01 per cent.

Test pieces were shaped and tested with the following results:

—	Thickness of plate.	Ultimate stress.	Elongation.	Contraction of Area.
		tons per sq. in.	*per cent. in 8 ins.*	*per cent.*
Cupreous	0.51	35.3	24	38.4
	0.52	35.1	21	40.3
	0.52	33.8	20	30.5
	0.51	34.9	22	42.8
	0.52	34.6	19	31.0
Normal	0.48	35.8	20	37.5
	0.49	36.3	22	30.9
	0.47	37.4	19	41.1
	0.48	36.6	20	32.3
	0.49	36.7	21	42.7
AVERAGE RESULTS.				
Cupreous	0.52	34.7	21	36.6
Normal	0.48	36.4	21	36.7

The difference in the thickness of the plates is sufficient to account for the greater tenacity of the normal steel. The results show that the copper is without influence on the properties of the steel when cold.

A large number of pieces were tested by bending, but no difference could be detected between the cupreous and normal steels.

WELD TESTS.

Both the cupreous and normal steels appeared to weld equally well, but this part of our research is not quite completed.

CONCLUSION.

The above results confirm most fully, as far as they go, the conclusions of Mr. Colby and Mr. Lipin. They show that copper has no more right to have the character of making steel red-short than carbon. They prove—

1. That between 0.5 and 1.3 per cent. copper has no deleterious effect on either the hot or cold property of steel.

2. That a very large amount (2 per cent.) makes the steel more liable to be overheated.

3. In small quantities it slightly raises the tenacity and the elastic limit, but, unlike phosphorus, does not sensibly make the steel liable to fracture under sudden shock. Like carbon, it reduces the power of the steel to extend under stress, but this is not pronounced when the quantity is small. The effect is more marked when large quantities are present.

4. That if the evidence of the open-hearth steel trial can be confirmed, copper, instead of producing redshortness, has the contrary effect of changing redshort steel into steel which will roll without cracking.

TRIPLE-SCREW SHIPS.

By Rear Admiral Geo. W. Melville, Engineer-in-Chief, U. S. Navy.

[From "Marine Rundschau."]

My attention has recently been called to an article in the "Marine Rundschau" for March, 1901, which takes as a basis my paper before the Institution of Naval Architects in March, 1899, and then discusses the subject of triple-screw propulsion very thoroughly, going, indeed, at great length into some of the nautical or tactical features which it was not my purpose to discuss. Although the writer simply signs his initials, F. B., thus leaving to conjecture his personality, there can be no doubt that he has given the subject most careful study, and I am glad to express my appreciation of his thorough discussion of the nautical and maneuvering side of the case, which I believe will materially assist in bringing out the benefits to be derived from the use of three screws.

Although he mentions my paper as having read it carefully, I find that he does not seem to have grasped clearly some of the points I made; and, while I do not believe in "thrashing over old straw," it may be helpful to all who are studying the question, if these points are restated and further elucidated.

In spite of the fact that I have repeatedly stated otherwise, the idea seems to have considerable currency that three screws were used on the *Columbia* and *Minneapolis* for the purpose of securing economy at low speeds by the use of the center screw alone with the wing screws uncoupled. It is true that we did anticipate that there would be this incidental advantage, which experience has shown to have been a mistake *with all screws of the same size*, but my reason was solely on account of constructive considerations. Further than this, friends of the highest professional standing and greatest experience warned me that the

maximum speed would require a greater expenditure of power than if twin screws had been used, and I was prepared to accept this view, as none of us had anything but *a priori* reasoning to guide us—not an infallible guide by any means.

As I have shown in my paper before the Society of Naval Architects and Marine Engineers, in November, 1894, the trials of the *Columbia* and *Minneapolis*, when compared with those of the *New York* and *Olympia*, proved conclusively that there was a decided economy of propulsion at full power with the three screws, due to better efficiency of propulsion; that is to say, the ratio of towing power to propelling power was higher in the triple-screw ships than in those having twin screws; or, put inversely, the ratio of propelling power to towing power was lower for the triples than for the twins. For I stated in another paper, previously referred to ("The Logical Arrangements of the Motive Power of Warships," read before the Institution of Naval Architects, March 23, 1899), regarding results from actual trials of large ships as against tank experiments: "The latter serve very well for determining the actual resistance of a hull, but not for fixing the economy of propulsion, or the ratio between the towing and indicated powers. It is in the increase of efficiency, and not in any decrease of resistance, that the economical advantage of triple screws must be found."

I am well aware that this view was not accepted by all, or, rather, my explanation of it, but the facts are undoubted. Probably no data were ever obtained with more care than in the trials of the four ships named. There was an ample corps of trained observers; the system of observations was the result of many trials; and, what is not always looked after, the indicators had been most carefully calibrated by the same experts in all cases, and the apparent pressures were corrected for the errors of the instruments. There can be no doubt, therefore, of the accuracy of the data.

In the paper of 1894 the comparison of the two systems was made in two ways, according to Froude's law, and also by an approximate computation of the hull resistance. Somewhat to my own surprise, the two methods gave almost identical results.

In the discussion, the author of the book from which I had taken the data and formulæ for computing the hull resistance, claimed that I had not used the proper coefficients because the hulls were not alike, and gave a new formula, apparently invented for the occasion, which he said "he had found better adapted to such cases." As these were the first cases of just the kind, the suspicion of special invention is very strong, especially as the formula was so arranged as to give the ship's length a very undue inverse weight in calculating wave-making resistance. With this special formula, assisted by some errors of computation, the efficiencies were reversed and made to appear as if the twin screw ships were the more efficient. However, no question was raised as to the comparison by Froude's method, which is, of course, the more accurate, and is, in fact, the same that is now used in predicting results from model experiments and in comparing such experiments. I may add that the special formula, when applied to large and fast liners, which compared about as the hulls of the two sets of naval vessels, gave absurd results, proving still further that it was invented simply as an attempt to discredit the remarkable results of the triple-screw ships. I have been told that model experiments have shown that there is no gain from three screws, but I do not believe that model experiments on screws have yet attained any such authoritative acceptance as to discredit actual trials.

The fact is, of course, that no strictly comparative experiments of the two systems have yet been made; that is, there has not yet been a case of the building of two ships with identical hulls for the same speed, and differing only in having one driven by twin and the other by triple screws. Nor have the experiments with either the *Kaiserin Augusta* or the *Minneapolis* been such as to make a crucial test, *at full power*, of the merits of the two systems. The comparable experiments on the *Augusta* were at such low powers that cylinder condensation alone with three engines would more than neutralize any gain in propelling efficiency. Indeed, I think it surprising that the three engines made such a good showing when developing about one-fourteenth of full power.

The experiments with the *Kaiserin Augusta* are, however, of the highest value, and they call attention in a marked way to a great advantage of the system of a large central engine and small wing engines, proposed in my paper of 1899. In all cases where the center screw was used alone, the wing screws being uncoupled, the slip was abnormal, running from 31 to 39 per cent. Now, in well-designed machinery this can mean only one thing—that the central propeller, under these circumstances, was too small, that is, of inadequate surface. This is really obvious at a glance, but will be still more evident if we compute the indicated thrust.

Now, when the center screw is designed to take the thrust of half of full power and the wing screws each one-fourth, we not only have 17 per cent. greater area to take the thrust, but, on account of having reduced the idle screws, we have reduced the resistance, so that we have less thrust on the larger screw. This will reduce the slip to normal proportions and will, I am sure, give us the economy which was originally anticipated, although unadvisedly, from the use of the center screw alone. It must be remembered that the anticipated *economy of steam* has been realized, but the radius of action was not increased on account of the increased resistance due to the wing screws and the abnormal slip due to the inadequate size of the center screw when working alone. The economy of steam was very clearly demonstrated in some experiments made in 1896 by my direction on the U. S. S. *San Francisco* in the Mediterranean. She is a twin-screw ship, and the trials were with one and two screws, each lasting for forty-eight hours, and at about the same speed of the ship. When working with one screw the indicated horsepower was 873, revolutions 65, and coal per indicated horsepower 2.91 pounds. With two screws the indicated horsepower was only 766, the revolutions 52, and the coal per indicated horsepower 3.45 pounds. The helm angle when using one screw was 9 degrees, I believe; therefore, we are entitled from all the available data to conclude that with the plan proposed in my paper of 1899 we should not only get the increased *steam economy*—of that we are certain—but that this would not be offset, as in the case of propellers of equal size, by the increased resistance when dragging. In my paper of 1899

I pointed out the advantage of the large central screw, but discussed it in a somewhat different way. A further advantage of this arrangement and proportion of the propellers is that we can, with this system, use the wing screws with almost the same steam economy as the central screw. The combined power of their engines is the same as that of the center engine, and there is only the increased surface of the cylinders to cause any reduction of steam economy. Where the propellers were all of the same size the center one was too small, and the use of the two wing engines for low speeds gave very unfavorable conditions for steam economy. In the new system we shall have the same adequate propelling surface, either with the wing screws or with the center screw alone, and in either case our reduced power is a fraction of only half the total power, instead of two-thirds, as in the case of the wing screws, where all are alike.

"F. B.," in stating the disadvantages of triple screws, speaks of the increased complexity and greater length required in the ship. It is perfectly evident that he referred to ships with cylindrical boilers, all forward of the engines. In my paper of '99, it is shown that the engines occupy no greater length in the ship than would those driving twin screws, and, indeed, that space is much better utilized, as the small wing engines are right alongside of the central engine, this being possible on account of their shorter stroke. It is also pointed out that this permits the location of the engines where the effects of vibration will be a minimum. It also enables a better trim of the vessel to be obtained by putting part of the boilers abaft the engines. This meets the objection raised with respect to the location of the after turret.

With respect to the matter of alleged increased complexity of piping and auxiliaries, attention may be called to the fact that multiplication does not necessarily mean complication. Experience has shown that it is just as easy for a man to handle twin-screw machinery as it formerly was to handle that for one screw, and the experience on the *Columbia* and *Minneapolis* has been the same with three screws. Indeed, this is simply one case of what all recent experience has shown with all kinds of machinery. Along with the increased amount of machinery have come facil-

ities for readier manipulation and increased knowledge, and also our own increased ability, so that it is really an easier matter now to have thorough control of even triple screws than it was twenty years ago for a single screw. The people who *may* find the triple-screw system complicated are the deck officers, but they have now such aids in the shape of annunciators, shaft and speed indicators, voice tubes, etc., that a very short experience renders them thoroughly *au fait*. Each engine room and fire room has its own crew, who have no more bother than in a single-screw ship. As for the piping, there is more of it, with more valves, but there are more mechanics to keep things in order. It must be remembered, too, that there is an increase of safety in the smaller pipes. The use of what we call "manifolds" in the piping system, which in a way are analogous to the busbars of an electric switchboard, greatly simplifies what might otherwise be very complex.

In connection with this allegation of increased complication I may refer to the matter of auxiliaries, of which special mention has been made. As far as their care and manipulation are concerned, the increase in the working force takes care of that. With respect to economy, it is to be noted that as the main engines will be operating at a higher percentage of full power, so will the auxiliaries, with better steam economy as a consequence. It is also to be noted that we can, in effect, make them a part of the main engine by taking steam from one receiver and exhausting into another, thereby getting practically the same economy as the main engine; or we can exhaust into one of the feed heaters with consequent economy.

The plain facts are that hardly any objections from an engineering standpoint can be asserted that will bear serious investigation, and least of all this one of complication. When the *Blake* and the *Blenheim* of H. M. Navy, and the *New York* and the *Brooklyn* of the U. S. Navy, were brought out with four sets of engines, which is worse, of course, if complication really is so objectionable, not a word was said about complication, even where such a plan was used, as in the British ships, of disconnecting all the connecting rods of the idle engines. The Amer-

ican system used a clûtch coupling between the two sets of engines.

From an engineering standpoint the system of half the power in a central engine and one quarter power in each wing engine has the following, among other great advantages, for war vessels:

Increased economy at full power.

Increased economy at reduced power.

Readiness for changing to full power when working at reduced powers.

Reduced engine-room space.

The central screw is of adequate size to get all the benefits derivable from using a single engine at reduced powers.

Vibration is minimized.

Two independent plants, each capable of economical propulsion up to three-fourths speed.

The many advantages of the triple-screw system are well set out by "F. B.", but I want to emphasize the one relating to the decreased liability to accident to the propellers on account of decreased size, and to point out that the scheme in the '99 paper carries this to the fullest extent by using wing screws of the least practicable diameter. This advantage in the case of ramming I believe to be real, but, as yet, we can only discuss this *a priori*. We have, however, had a great deal of practical experience with damage due to striking docks, etc. When the *Olympia* was coming home through the Suez Canal one of her screws came in contact with the *bank*—not the *bottom*—and was bent so that the rest of the trip had to be made with one screw. Again, a number of our torpedo boats were sent on a trip involving the passage of two canals. Nearly every one had her screws damaged by striking the *sides* of the locks or of the banks, on account of the protruding twin screws of relatively large diameter.

As an explanation of the amount I have written about triple screws, I may point out, as I have done before, that I am not urging the adoption of a scheme originated by me. I can hardly be called a convert, for I have never opposed them, but I am really a follower, as far as the principle is concerned. The only credit I can claim is the courage of my convictions in using them

for a much larger power than had been attempted up to the time they were used in the *Columbia* and *Minneapolis*. My interest is, however, now to assist in the campaign of education, which will, I firmly believe, result in their general adoption. To a certain extent, I feel the natural desire of every pioneer to have his work approved. So far as the design of our own triple-screw ships is concerned, they exceeded what we demanded and expected of them, and are, indeed, an unqualified success. The fact that they have not as yet been repeated in the American Navy, and a certain amount of sneering criticism at certain features, have made me feel that there is ample justification for bringing the subject repeatedly before engineers and naval men generally, and discussing the subject from various aspects in the effort to secure complete elucidation and agreement of opinion. As in the case of all new problems, our first attempts at solution are apt to be only partially successful covering the main points, but missing some which, while subsidiary, are still of real importance. One of these points is the question of economy at low powers, of which I believe to have reached a reasonable solution in the use of a large central engine and two small wing engines. Some of the disadvantages enumerated are real, but can be obviated; others are largely fanciful, based on insufficient acquaintance with the details of machinery. What I am urging is to give this system, like all promising innovations, a fair and sympathetic test. When it has proved that it has advantages of great weight—and of this there is no doubt—we should take the next logical step, namely, to repeat with such modifications as are suggested by experience with a view to removing disadvantages. To take the attitude of unwillingness to make further tests on such weak grounds as "increased complication," is to put ourselves back more than a hundred years, and is utterly unworthy of the scientific spirit of the Twentieth Century.

NOTES.

THE TRIALS OF THE *MINERVA* AND THE *HYACINTH*.

The trials of these two vessels under the direction of the Boiler Committee, referred to in their Interim Report (See page 362), have excited the greatest interest in naval and in engineering circles, but as the report of the Committee has not yet been made public, the results here given cannot be regarded as final, though they are from authoritative sources.

As a better understanding of the conditions will probably be had if particulars of the ships are known, the principal dimensions of their hull and machinery, and the results of their official contract trials, are given below.

	Minerva.	*Hyacinth.*
Length between perpendiculars, feet	350	350
Breadth, extreme, feet	53.5	54
Draught, mean, feet	20.2	20.5
Displacement, tons	5,600	5,600
Type of engine	Triple.	Triple.
Steam pressure, pounds	155	250
Cylinders, H.P., diameter, inches	33	26
I.P., diameter, inches	49	42
L.P., diameter, inches	74	48 (2)
Stroke, inches	39	30
Condensing surface, square feet	...	9,580
Boilers, type	Cylindrical.	Belleville.
steam pressure	155	300
number	8	18
grate surface, square feet	649	750
heating surface, square feet	18,696	24,000
Screw propellers, direction of turning	Outward.	Inward.
Weight of boilers and water, tons	558	470

OFFICIAL TRIALS.

	Minerva.		*Hyacinth.*	
	Nat. draft.	Fd. draft.	Nat. draft.	Fd. draft.
Steam pressure at engines.	151	152	...	241
Air pressure	.27	1.02	...	.25
Revolutions per minute	127.9	137 6	...	* 180
I.H.P	8,216	9,902	7,718	10,536
Speed by patent log	19.6	20.34	17.34	19.4

* Designed.

As bearing on the speed of the *Hyacinth*, the results of the official trials of the *Hermes* and *Highflyer*, sister vessels to the *Hyacinth*, are given below. See also page 281.

	Hermes.		*Highflyer.*	
	Nat. draft.	Fd. draft.	Nat. draft.	Fd. draft.
I.H.P.	7,705	10,264	7,644	10,344
Speed by patent log	18.8	20.5	19.4	20.1

The ***Minerva*** was built at Chatham dockyard, and the *Hyacinth* by the London and Glasgow Shipbuilding and Engineering Company.

Each ship carried out three series of trials, one of 24 hours' duration at 2,000 indicated horsepower, one of 24 hours' duration at 5,000 indicated horsepower, and one at cruising full power for eight hours in the *Minerva* and for twelve hours in the *Hyacinth*, the indicated horsepower in this trial being 8,000. Subsequently, the *Hyacinth* ran a trial at 10,000 indicated horsepower.

The results as published are:

	Minerva.	*Hyacinth.*
Indicated horsepower	2,142	2,053
Speed, knots	12	12
Coal per indicated horsepower	2.2	2
Water evaporated per pound of coal	8.54	9.69
Indicated horsepower	5,155	4,992
Speed, knots	16	16
Coal per indicated horsepower	1.74	1.84
Water evaporated per pound of coal	8.87	9.41

	Minerva.	*Hyacinth.*	
Indicated horsepower	8,114	8,105	10,181
Speed, knots	18	18.5	20
Coal per indicated horsepower	2.4	1.8	2.1
Water evaporated per pound of coal	8.19	9.89	8.8

An analysis of these figures shows that the water used per indicated horse power was:

	Minerva.	*Hyacinth.*
At 2,000 indicated horsepower, pounds	18.79	19.38
At 5,000 indicated horsepower, pounds	15.43	17.31
At 8,000 indicated horsepower, pounds	19.65	17.80
At 10,000 indicated horse power, pounds	...	18.48

No mention has been made as to whether the moisture in the steam was determined on these trials, but presumably it was not.

Subsequently to the 8,000 indicated horsepower trial of the *Minerva* retarders were put in her tubes and another trial made with one-half her boilers in use, and at the same rate of combustion, resulting in 9 per cent. economy in fuel.

Upon the conclusion of these trials both ships were docked, in order to have their bottoms cleaned, and after coming out of dock had their bunkers filled with hand-picked coal. They then started at the same time from Plymouth for Gibraltar, with orders to maintain as nearly as possible 7,000 horsepower, and, after reporting at Gibraltar, to continue steaming at the same speed until their coal supply was exhausted. The *Minerva* was the first to report, and returned July 13th, after having steamed about 150 hours, about two hours of which were consumed in making repairs. She had about 30 tons of coal left when she anchored. The *Hyacinth* put into Gibraltar July 11th, 103½ hours after starting, "owing to having lost a considerable quantity of water through leaky feeding connections." No information has been published regarding her coal supply, but the "London Times," from which the above quotation is made, says that, "taking into consideration the time under way and the horsepower developed, the coal consumption per pound of water evaporated appears to be slightly in favor of the *Hyacinth*, but for practical purposes the results may be taken as equal. It is only fair to note, however, that the loss of water, through defective feed connections, must have told considerably against the efficiency of the *Hyacinth* boilers." It does not, however, appear that this loss of water was not counted as a part of the evaporation per pound of coal, which cannot be determined without knowing how the feed water was measured.

The return home was to be made at maximum speed, each ship having taken on coal from the same pile. The "Times" gives the following account of the race:

"At 4 o'clock last Wednesday afternoon the signal was made "Light up and proceed to England." Three-quarters of an hour later the *Hyacinth* was steaming at 18 knots. At a quarter past 5 the *Minerva* was following at full power. At 4

o'clock on Thursday morning the *Hyacinth* had a lead of 9 miles, and then the leading ship ran into a fog bank, where she was joined by her rival. They both eased down to 8 knots until 10 o'clock, when the fog lifted, and the *Minerva* steamed away at 8,400 indicated horsepower, and the *Hyacinth* at 9,400, but, in spite of her inferior power, the *Minerva* drew away and increased her lead at the rate of 1.3 knots. This was, from a scientific point of view, the most instructive part of the race, as it showed that the *Minerva* possesses an advantage either in the form of her propellers or in the superiority of her lines, for when the *Hyacinth* made a sprint of three hours at 10,000 indicated horsepower, she merely churned the water without appreciably increasing her speed. On Thursday night, when in the Bay of Biscay, another fog was encountered, and for ten hours both ships proceeded at 7 knots. Then they went ahead again at the same power as before. On nearing Ushant there was another fog, which lasted six hours, and again speed was reduced to 7 knots, but the *Minerva*, being the leading ship, cleared an hour before her rival, and she increased the lead by half an hour by the time Spithead was reached. During the run home no difficulty was experienced in keeping 90 per cent. of full power in the *Hyacinth*, and the *Minerva* could keep her full power at natural draft with equal ease, the retarders affording considerable assistance. The net results are of an unsensational character. The *Hyacinth* is much more powerfully armed than the *Minerva*, but her 2,000 additional horsepower gives her no appreciable advantage. The trial has demonstrated that the reputed speed of the *Hyacinth* class is fictitious, for, owing to causes which cannot here be inquired into, it is now known that any effort to attain more than 9,000 horsepower is labor and fuel wasted. Thus at 7,000 indicated horsepower the speed of the *Hyacinth* was 17.9; at 9,400 it was 19 knots; and at 10,000 indicated horsepower it was still 19 knots. On the voyage out Vice Admiral Sir C. E. Domvile, Mr. J. Milton and Mr. W. H. Wood, secretary, took passage in the *Hyacinth*, and Mr. J. Bain, Mr. J. List and Commander M. E. Browning, secretary, were in the *Minerva*. On the voyage home Mr. Milton and Mr. List changed places. The records

were taken by fifty employees sent from Portsmouth dockyard, who were under the direction of Mr. Burner, assistant to the chief engineer of Portsmouth dockyard."

The *Minerva's* time was 75½ hours, and her average speed when not slowed down for fog, 18.67 knots; that of the *Hyacinth* about 18 knots.

The following editorial from "Engineering" may be taken as representing the views of one of the parties to this controversy:

"So far as can be judged by details already made public, the trials of the *Minerva* and *Hyacinth* leave us very much where we were in regard to our estimate of the value of the Belleville boiler for naval purposes. Former trials with vessels of the Royal Navy have shown that this type of steam generator can be worked with a fuel economy equal to that of the cylindrical Navy boiler, and in many respects the Belleville boiler is superior to the older type. In fact, it may be said that, so far as trial-trip performance is concerned, and with everything tuned up to concert pitch, there is little to be learned by those who are not wilfully blinded by prejudice or self interest. That the Belleville boiler is, in certain respects, superior for warship purposes to the Navy boiler, which it superseded, is a conclusion we have come to as the result of observation; but our experience has not enabled us to decide on the question of durability. This is an important point upon which we have been always careful to reserve our opinion. But although the Belleville boiler—with the above reservation—may safely be pronounced superior to the old Navy type, it is equally safe to say it is not the type that will last; indeed, there are water-tube boilers already in the market that are its superior. Considering the importance of circulation in the working of a water-tube boiler—in fact, more or less, in the working of all boilers—it is surprising how partial our naval authorities are to the horizontal-tube type. In other navies we find vertical or approximately vertical boilers installed in large vessels, both cruisers and armored ships, with satisfactory results; but the Royal Navy, in making the one advance from shells to tubes, seems to have exhausted its enterprize; to be incapable of grasping the fact that in this practically fresh

field of invention there must necessarily be ample opportunity for improvement, especially with so many capable engineers bending their minds to the subject.

"As we have said, the details published respecting the trials of the two cruisers have not added much to our stock of knowledge, but they appear to have been useful in silencing some of the most reckless and irresponsible critics of Admiralty procedure. In fuel economy the Belleville boilers of the *Hyacinth* show to considerable advantage over the return-tube boilers of the *Minerva*. According to an account contributed to the 'Times' by 'a correspondent'—evidently an engineer—the water evaporation on the *Hyacinth* was effected at a much lower cost of fuel than on the *Minerva*. Three trials were made. [Here follows a statement of the results published on page 699.] A fourth trial at absolutely full power was on the program, but it was considered undesirable to force the shell boilers of the *Minerva* to their full extent. The *Hyacinth's* engines developed 10,181 indicated horsepower for eight hours, the evaporation of water per pound of coal being 8.8 pounds.

"After these trials, 'certain modifications,' of a nature not stated, were made in the *Minerva's* boilers, with the result that the fuel economy was increased 9 per cent. This fact detracts from the value of the comparison throughout. One would have thought that enough was known about the working of cylindrical boilers to enable those of the *Minerva* to be brought up to their full efficiency before the trial commenced.

"The remaining trial was a test of the two ships rather than a trial of their respective types of boilers; although, of course, were the vessels absolutely identical in all other respects the success of one would have meant a triumph for her boilers. Unfortunately, the ships are by no means identical in other respects.

"In the first place, the hulls are of different dimensions. They are both 350 feet long, but the *Hyacinth* is 6 inches wider (54 feet beam) and 4 inches more draught (20 feet 6 inches). As the displacement is the same in both cases—5,600 tons—there is evidently a difference in model. The engines, too, necessarily differ, as those of the *Hyacinth* are designed to run at an initial

pressure of 250 pounds, or 100 pounds above those of the *Minerva*. The *Minerva* was designed for 9,600 indicated horsepower at 140 revolutions, and the *Hyacinth* for 10,000 indicated horsepower at 180 revolutions. The weight of the Belleville boilers of the latter is 461 tons, and that of the cylindrical boilers of the *Minerva* 557 tons. The *Hyacinth* has a more powerful armament than the *Minerva*, the weight saved by the lighter boilers of the former being devoted to giving her heavier guns, thus taking from the ship, in regard to speed, some of the advantage her water-tube boilers should secure.

"The race home from Gibraltar to Portsmouth was a failure, due chiefly to fog. The *Hyacinth* got away half an hour before her competitor, owing to her getting up steam more quickly. After 24 hours' steaming she had an estimated lead of nine nautical miles, and then ran into a fog, which caused both ships to ease to 8 knots. On the fog lifting, the *Minerva* steamed away with her engines developing 8,400 indicated horsepower, whilst the *Hyacinth's* machinery developed a 1,000 horsepower more. In spite of this the *Minerva* drew away at a rate which gave her an advantage in speed stated to have amounted to 1.3 nautical miles per hour. As a test of boilers the race was evidently inconclusive. It is said that the *Hyacinth*, which made a three-hours' run at 10,000 indicated horsepower, gained no advantage in speed from her additional power, as 'she merely churned the water without appreciably increasing her speed;' and 'her 2,000 indicated horsepower gives her no appreciable advantage.' Certainly 10,000 horsepower is a high ratio for a length of ship of 350 feet; and one knows how rapidly the demand for power increases to get the last half knot or so; but the ships are not disproportionately broad, and one can hardly imagine that six-inch variation in beam would make so great a difference. It is said, however, that at 7,000 indicated horsepower the speed of the *Hyacinth* was 17.9 knots, at 9,400 indicated horsepower it was 19 knots, and that only the same speed was reached when the engines were working at 10,000 indicated horsepower."

The other side may be said to be fairly represented by this editorial from "The Engineer."

"The competitive trials of H. M. *Minerva* and *Hyacinth* terminated on the 20th instant (July) with the arrival at Portsmouth of the first named cruiser at 9·50 P. M., and the second at 11·25 P. M. No official figures are available, but the statements published are, we have reason to believe, substantially accurate. It would be waste of space to recapitulate the history of the experiment. During the run from Plymouth to Gibraltar the engines of both vessels were worked as nearly as possible at 7,000 horsepower. Each ship reported herself on arrival, and then continued steaming, with the intention of emptying her bunkers, and so ascertaining her endurance at the stated power. The *Hyacinth* steamed altogether for 103.5 hours, and the *Minerva* for 150 hours. How much coal the *Hyacinth* had on board then we do not know. She was driven into Gibraltar, because her boilers leaked so much that the fresh-water feed could not be maintained, the evaporators being overpowered. The *Minerva* lost about two hours repairing machinery. It is stated that at 4 P. M. on Wednesday, the 17th, the signal was made 'Light up and proceed to England.' Three-quarters of an hour later the *Hyacinth* was steaming at 18 knots. At 5·15 P. M. the *Minerva* was steaming at full speed. On the run home fogs were encountered three times, by which the ships were delayed. But always the *Minerva* was the faster of the two. A boiler tube burst on board the *Hyacinth*, and a fireman was so severely scalded that he had to be sent to Haslar Hospital. Both ships are to join at once in the maneuvers.

"A consideration of the circumstances of the trial shows that the results were curiously typical. In every way they support the contention of those who advocate the superiority of the Scotch boiler over water-tube generators; but they do more than this. They go to show that the recent high-pressure practice of the Admiralty is in no wise better than the older system. It will be remembered that the *Minerva* is comparatively an old vessel, built in 1895. She has triple-expansion engines with cylinders 33 inches by 49 inches by 74 inches by 3 feet. The boiler pressure is 155 pounds; revolutions, 140; indicated horsepower, 9,600. She is at all powers faster than the *Hyacinth*;

precisely why no one knows. Carefully conducted tank experiments proved, we understand, that what may be called the tow-rope resistance of the two cruisers is about the same. No doubt the defect of the *Hyacinth* lies in the way in which her power is applied, that is to say, in her machinery. The performance of the *Minerva* was quite uneventful. The only defect manifested was the breakage of the bolt of an eccentric strap, and the consequent bending of one of the straps. The defect was made good with spare gear in two hours. The ship was quite ready to start again on her homeward run the moment her bunkers were filled.

"Leaving the *Minerva* for a moment, we turn to the *Hyacinth*. During the first hours of the run out all went well. Then the loss of water began. The evaporators can supply between 6 and 7 tons of distilled water per hour; but this was insufficient to make up the loss. A very curious feature of this loss is that it was found impossible to trace it to its source. The connections and pipes seemed tight, water did not run into the furnaces, nor was it found in the bilges. The loss was not due to priming, of course, because the water would have reappeared in the hotwell. The only explanation is that a multitude of very small leaks are equal in effect to one or two large leaks, and that the water was evaporated and went up the chimneys. A most careful overhaul took place at Gibraltar, and there everything was tested by the hydraulic pump. Not satisfied with this, the ship was taken out of harbor and run for twelve hours to make certain that every joint was tight. This being done, she returned to harbor; fires were drawn, and the boilers cooled down.

"We now come to the run home. The statement that within less than two hours from the receipt of the signal to light up, the *Minerva* was at full speed, may appear incredible. It is, however, perfectly true. No wonder will be felt that the *Hyacinth* with water-tube boilers should get steam quickly, but the performance of the *Minerva* comes as a surprise. It was not a case of banked fires. While in harbor one boiler out of the eight was under steam to supply electric light, &c. On the day before the return voyage began both ships were moved into the

outer harbor, or roadstead; and, as there was some wind, the pilot refused to move the *Minerva* with only one boiler going. Steam was, therefore, raised in two other boilers. As soon as the vessel was moored the fires were entirely drawn, the steam blown down through the condensers, the smoke-box doors opened, and the boilers cooled down for about twenty-four hours. When the order to light up came one boiler was carrying 150 pounds; in two boilers the temperature of the water was at 190 degrees Fahrenheit; in the five remaining boilers it was 90 degrees Fahrenheit, that being the temperature of the stokehold—not much in excess of that of the air on shore. The engines were still warm. Both ships started the moment the engines could give them steerage way. It is no matter of wonder that the *Hyacinth* should get away quickly, but the fact that the *Minerva* was so little behind cuts the ground from under the feet of those who maintain that the Scotch boiler is too slow for naval purposes. The draft was never forced; it was assisted by the fans, the pressure not exceeding about half an inch. No doubt the result was secured by boiling the top water, the bottom water remaining comparatively cold. If a hydrokineter had been used several hours would have been lost. This is by no means a solitary instance of what can be done in an emergency. The boilers were in no way injured. On the run home they were properly treated. They were never forced beyond their legitimate power—8,400 indicated horsepower—which they can attain with assisted draft.

"As to the *Hyacinth*, we are told that some anxiety was felt about her Belleville boilers, and this seems to have been justified by the deplorable accident to which we have referred. We have said that the performance of the two ships is opposed to the theory that the high pressures recently adopted by the Admiralty are economical. The *Hyacinth* has four-cylinder triple-expansion engines, the cylinders being 26 inches by 42 inches by 48 inches by 48 inches by 2 feet 6 inches, maximum revolutions, 180. It is officially admitted that the engines of the *Minerva* are more economical, although it is claimed that the boilers of the *Hyacinth* evaporate about 9 per cent. more water per pound of

coal. So far as can be said, in the total absence of official figures, it appears that the *Minerva* burns less coal per mile, other things being equal, than the *Hyacinth*. The engine friction of the latter, because of the short stroke, high speed and high pressure—250 pounds—must be greater than that of the *Minerva's* machinery. The coal burned for all purposes, expressed in terms of indicated horsepower, was as nearly as possible the same for both ships, just under 2 pounds.

"The history of the trial is, as we have said, typical. We have the steady old Scotch boilers, fairly used, and doing their duty perfectly in the one vessel, and in the other we have the Belleville boiler doing as it would seem it always does when pressed. The ship could hardly reach Gibraltar at seven-tenths of her full power, the old trouble, leakage, driving her into port; and be it remembered that the *Hyacinth* is comparatively a new vessel—1898—that her machinery has been in charge for many weeks of Mr. Gaudin, and that nothing was left undone to make her a success. The *Minerva*, on the other hand, working up to a higher fraction of her full power, gave no trouble whatever and beat the *Hyacinth* in speed.

"A statement appears in the pages of a contemporary to the effect that when it was found that the *Hyacinth* was being outpaced by the *Minerva* her Belleville boilers were forced up to 10,000 horsepower, yet the ship went no faster through the water: 'The *Hyacinth* is much more powerfully armed than the *Minerva*, but her 2,000 additional horsepower gives her no appreciable advantage. The trial has demonstrated that the reputed speed of the *Hyacinth* class is fictitious, for, owing to causes which cannot here be inquired into, it is now known that any effort to attain more than 9,000 horsepower is labor and fuel wasted. Thus at 7,000 indicated horsepower the speed of the *Hyacinth* was 17.9; at 9,400 it was 19 knots; and at 10,000 indicated horsepower it was still 19 knots.' This is only partially true. The particular result named seems to have been due to the state of the weather, and to no other cause. Both ships are affected by rolling, and that to an extent which deserves investigation.

One type of roll appears to have a greater effect in reducing speed than any other; why, no one, so far, seems able to explain.

"The result of the whole trial is precisely agreeable to our forecast. It has added nothing very new to the existing stock of knowledge. The *Minerva's* machinery behaved just as it has always done. Her Scotch boilers maintained their reputation, and showed once more by how little the Scotch boiler failed a few years ago, and then only as the result of bad design and improper management. The Belleville boilers of the *Hyacinth* again did just what was to be expected. It will be remembered that we said that the only novelty to be anticipated in their performance would be that they had gone to Gibraltar and come back without a breakdown. This novel experience was not provided. We venture to think that in the light of the results of this trial the Admiralty may feel thoroughly justified in proceeding to fit the ships of the Navy with properly-designed cylindrical boilers, until such time, say five years hence, as they have reason to believe that a really satisfactory water-tube boiler is available."

THE HAVANA DRYDOCK.

The negotiations have been completed for the purchase of this dock from the Spanish Government, and it is possible that it may be towed to the Philippines for use at Cavite, or at the new station at Olongapo. It was built in 1897 by Messrs. Swan and Hunter, Wallsend-on-Tyne, England, from the designs of Messrs. Clark and Stanfield, and was towed to Havana. Two steamers were used for this purpose, one to tow and the other to assist in steering, a rudder and steam-steering gear having been fitted on the dock itself, in addition to which there were two masts, the foremast rigged with square sail.

It is a self-docking, steel, floating dock, consisting of five pontoons fastened between side walls which carry the pumping machinery and regulate the immersion of the dock. The pontoons are each 87 feet 11½ inches wide, the three middle ones, which are rectangular, being 75 feet long, and the end ones, which have pointed ends, 108 feet 4 inches long. There is a

space of 2 feet between the pontoons. The pontoons are each divided into four watertight compartments, and the side walls, below the engine deck, each into five compartments, making a total of thirty compartments in the dock. There are movable caissons or end gates.

The dimensions of the dock are:

Length over all, feet	450
Width between altars, feet	82
extreme, feet	109
Depth over side, feet	27.5
Draught when immersed 27.5 feet, feet	42.5
Freeboard when immersed 27.5 feet, feet	4.2

The pumping machinery consists of two generating plants, one in each wall, each comprising a boiler and engine with direct-coupled dynamo. The current is supplied to ten electric motors, five in each wall, which are placed vertically on the shaft of a centrifugal pump. These pumps are of sufficient capacity to lift the dock with a 10,000-ton ship in two and a half hours.

SOUTH BROOKLYN DRYDOCK.

There has recently been completed for public use at Brooklyn one of the largest floating drydocks in the world. It was designed by and constructed for the Morse Iron Works and Dry Dock Company, and is located near the new 40-foot channel, now being dredged along the South Brooklyn shore. The drydock itself is situated at the foot of Fifty-sixth street, the property of the company extending from Fifty-fifth to Fifty-eighth streets, and including land under water reaching some 2,000 feet into the harbor.

The floating drydock, which at present consists of five sections or pontoons, each 80 feet in length, has a total length of nearly 500 feet, which includes the 4-foot spaces between the pontoons and the 32-foot extensions at each end. When completed the dock will be between 700 and 800 feet in length. The pontoons are 120 feet in width, and the combined lifting capacity of the pontoons at present installed is 15,000 tons.

The pumps are electrically driven, the motors being of the induction type and the pumps of the centrifugal pattern. They are of sufficient capacity to dock an 8,000-ton ship in 40 minutes.

Each pontoon or section has the shape of a V. As stated above, each is 80 feet long by 120 feet wide, and has a depth of 15½ feet at the center. The two wings at each side measure 56 feet from the bottom of the pontoon to the top platform, on which the motors and the handwheels for the inlet valves are located. The sections are built of the best Southern pine, and a complete system of stiffening bulkheads is used, there being seven running longitudinally, or fore-and-aft, through each pontoon. Each section is provided with a number of inlet gates below the waterline, and sufficient ballast is carried to insure its sinking when the gates are opened.

On the floor of each wing is situated a centrifugal pump. Each pump is supplied with three suction pipes, two extending towards the two end chambers and one to draw the water out of the central one. There are in all six compartments, three on each side of the main central bulkhead; but in case of a breakdown, the two sets of compartments may be connected by means of sluice valves, and either pump can accomplish the entire task of pumping out the pontoon. This sectional arrangement makes it possible to dock a vessel which is considerably listed, by tilting the dock. After the pontoon has assumed the same angle as the listed vessel, the latter is secured on the dock, which is then made to assume a level position. The pumps have a capacity of 5,000 to 6,000 gallons of water per minute, and all suction pipes are 20 inches in diameter.

Each pump is connected by means of a vertical shaft to a 75-horsepower General Electric induction motor, which is housed in at the top of the pontoon, more than 50 feet above the pump. Three-phase current at 6,600 volts and 25 cycles to operate these motors is supplied to the company by the Edison Electric Illuminating Company, of Brooklyn. It is led to three 300-kilowatt General Electric airblast transformers, connected up in delta, located in a transformer house, where it is transformed down to 240 volts. A 2-horsepower induction motor is directly

connected to a blower which supplies the air for cooling the transformers. A duplicate set of three conductor cables has been installed to guard against a breakdown.

From the transformers the current is led to the switchboard, consisting of six panels, five of which are for the control of the motors. On one panel are mounted the polyphase wattmeters, one for the starting bus, at 140 volts, and one for the main bus, at 240 volts, as well as three 3,000-ampère, single-pole, quick-break knife switches for controlling the board. The voltmeter is mounted on a swinging bracket. On each of the five motor panels, each of which controls two 75-horsepower induction motors, are mounted two three-pole, double-throw oil switches, and two Thompson alternating-current ammeters, reading from 0 to 350 ampères.

On the back of the board are two sets of bus-bars, the lower ones being the starting and the upper ones the main busses. There are also two G. E. circuit breakers which control the starting busses. The main wattmeters are supplied with current transformers, which can carry a normal load of 2,300 ampères and an overload of 3,500 ampères for 30 minutes, the ratio being 140 to 1. The transformers for the starting wattmeters are designed for a normal load of 1,200 ampères and a 30-minute overload of 2,000 ampères, the ratio being 80 to 1. The motors on the pontoons are controlled entirely from this board, and after the motors have attained their proper speed, which the operator judges from the noise in the transformers ceasing, he throws them from the starting busses onto the main busses. The motors drive the pumps at a speed of 250 revolutions per minute.

The Edison Company also furnishes 2-phase, 60-cycle, 2,500-volt current for the lighting of the dock, which is done by means of arc lamps, located on the top platforms. The current is led to these lamps by means of flexible cables, supported in elevator loop fashion.—" Electrical World."

DOCK AT PORT MAHON.

A large self-docking pontoon dock, built for the Spanish Government by Messrs. Robert Stephenson and Co., Hebburn-on-

Tyne, England, has just been completed and towed to its destination. It was originally intended for the naval station at Olongapo, but has now been located at Port Mahon, Island of Minorca.

The requirements of the Spanish Government were that if a ship of 12,000 tons weight, with a length of 328 feet, be placed in the center of the dock, no part of the dock should be subjected to greater strain than 6.33 tons per square inch in extension, nor 7.6 tons per square inch in compression.

The principal dimensions are:

Length between perpendiculars, feet	450
Breadth, molded, over pontoons, feet	117
Depth, molded, of pontoons, feet	13.5
Camber of pontoon deck between side girders, inches	9
Breadth, molded, of side girders, feet	12.25
Depth, molded, of side girders above pontoons, feet	38.5
Distance over side girders, molded, feet	115
between side girders, molded, feet	91
shoring platforms, feet	85
pontoons, molded, foot	1
Lifting power of pontoons, tons	13,000

The bottom portion of the dock is built of iron, and is composed of six pontoons, each 74 feet 2 inches long by 117 feet wide, and 13 feet 6 inches molded depth. On the top of these are placed the side towers or girders, securely bolted to the pontoons, and binding them all together. The pontoons are also connected together by junction plates extending across the dock at each pontoon end.

The side girders are built of steel, on account of their having to take the strain when a ship is docked, and also as being mostly out of water they are not so liable to corrode. The pontoons are very strongly constructed, having eleven fore-and-aft bulkheads, nine of which are watertight, dividing each pontoon into ten watertight compartments. This makes sixty watertight compartments in the bottom of the dock, all of which were tested with a water pressure of 13 pounds per square inch.

Every fifth frame in the pontoons is a strong partial bulkhead, extending across the dock, and over these the bilge blocks are

placed. The center girder, over which the keel blocks are placed, is 1 inch thick, also under the keel blocks, 4 feet from the center on each side, two additional fore-and-aft bulkheads are placed. These, with diaphragm plates on every frame, make a very solid foundation under the keel blocks. The side towers have a safety deck about 14 feet above the pontoons, which prevents the dock sinking altogether, supposing the inlet valves were by any chance left open.

Each tower is also divided into ten watertight compartments. The center compartment of each tower is fitted up with the pumping installation, which consists of two large marine-type boilers, working at 120 pounds pressure, and two of Tangye's 24-inch centrifugal pumps, each worked by a separate engine; also one duplex drainage pump and fire pump, two duplex feed donkey pumps and a feed heater. This installation is duplicated in the other tower. Together the four main centrifugal pumps are capable of throwing 23,000 tons of water against a 28-foot head in two hours. The 26-inch main suction pipes and the main drainage pipes run along inside the side towers and branch down at each pontoon to a collecting box, from which pipes lead to each compartment of the pontoons. Each of these pipes has a separate valve, worked by a rod and wheel from the top of the side towers. Each compartment has also a wrought-iron air pipe, which is led up to the side towers and placed near the standard and wheel which operates the valve to the corresponding compartment. At the top of the air pipe is placed a gun-metal cock. The inlet pipes, which are 19 inches in diameter, are also connected to the collecting or distributing boxes, and each inlet pipe has a grid and valve worked from the top of the towers. Every water valve in the dock has an indicating plate and pointer, showing how much the valve is open.

Each pump, by means of valves, is arranged to suck from one or both ends of the dock, and each pump has a 24-inch valve on the discharge branch and also a balanced flap valve. The drainage pump is also arranged to suck from each compartment through a separate range of pipes, and there is a gun-metal drainage foot valve at the bottom of each branch pipe to each com-

partment of each pontoon. The drainage pump is also connected to a range of pipes, which are carried along the top of the side towers, for washing decks or for fire purposes. The compartments in the side towers are filled and drained through the main suction pipes, and they can also be drained from the deck of the pontoons. There are speaking tubes to the engine rooms from each tower and also from side to side.

The keel blocks, which are placed 3 feet centers, are of pitch pine, and are 3 feet 6 inches high. The lower blocks are 18 inches square, and each keel block has a cap piece of oak 6 inches thick. The blocks are fitted between angle irons and are securely dogged together. There are 24 bilge blocks, of very strong construction, placed on the dock, so that they can be shifted in or out, and on the top of each steel bilge block is a sliding block of oak, which is pulled into position under water by means of ropes led to the top of the towers. There are two shoring shelves inside the dock, 2 feet 6 inches wide, with a facing piece of elm 9 inches by 6 inches. The sides and ends of the dock are protected by two American elm fenders securely bolted between angles.

On the tower tops are placed fourteen large timber heads for mooring ships using the dock, and four mooring shackles are attached to the pontoon for mooring purposes. Wrought-iron ladders lead up from the pontoons to the shoring shelves and tops of towers. On the inner side of the towers in the stokehold, watertight doors are placed, giving access to the deck of pontoon and for discharging ashes. The engine rooms and stokeholds are ventilated by cowl ventilators and a range of ventilating pipes. Feed tanks are placed on each side above the boilers, each holding 25 tons of fresh water for feed purposes. There are also bunkers which will hold 30 tons of coal in all.

The dock has been so constructed that in the event of damage to a pontoon, or if a pontoon requires the bottom to be scraped and painted, it can be detached and docked on the dock itself, and repaired or repainted. This is done by disconnecting the bolts that hold the pontoon to the side girders and to the pontoons adjoining, disconnecting the suction pipes and valve rods

and letting water through the sea valve into the pontoon when it is disconnected. This causes it to sink below the level of the bottom side girders, and it can then be easily drawn out at either side. It is then turned round so that the narrow part faces the entrance to the dock. The dock is then sunk sufficiently to let the pontoon float over it. The water is then pumped out and the pontoon raised; after painting, the process is reversed, and the pontoon brought back into place and rebolted to the side girders.

The towing of the dock to its destination was done by three powerful tugs belonging to Messrs. Smit, of Rotterdam. There were two tugs towing, namely the *Zvarte Zee*, whose rope was of 20-inch Manila, and the *Oceaan*, having an 18-inch Manila tow rope. The steering was done by the *Zuiderzee*, whose check rope was of 13-inch Manila. Seven tugs were employed to take the dock down the river.—"Engineers' Gazette."

THE ALGIERS, LA., DOCK.

There has been completed by the Maryland Steel Company, at Sparrows Point, Md., a steel floating drydock which is intended to be located upon completion at the United States Naval Reservation, at Algiers, La., opposite New Orleans. Its length is 525 feet over blocks; it has an entrance of 100 feet in the clear between walls, and will have a maximum lifting power of 18,000 tons. It will be attached to two steel columns on shore by two steel lattice booms, articulated in all directions. The dock will, therefore, be free to rise and fall with the river, which is subject to frequent severe freshets, and sometimes rises to 20 feet above Gulf level. This connection will, at the same time, allow the dock to be swung inshore out of the worst of the current, which occasionally attains a speed as high as six miles an hour.

The general plans of the dock were made by Clark & Stanfield, of London, England, who were the designers of many similar docks, the principal of which was the Havana dock. Another large dock of the kind is a commercial dock, which was also built in England, and was towed to Stettin, Germany.

Seneral modifications and improvements were added to the first plans submitted, to meet the requirements of the Bureau of Yards and Docks, the details of these improvements being worked out by the engineering department of the Maryland Steel Company. Among other changes the structural strength throughout the pontoons was increased, giving the dock a maximum capacity of 18,000 tons when the deck or floor is awash, or 15,000 tons with a freeboard of about 2 feet.

The specifications, with these changes included, call for a transverse strength sufficient for docking a battleship of 15,000 tons with the entire weight carried on the keel blocks. The specifications require that the time required for lifting a vessel shall be $3\frac{1}{2}$ hours from the time the keel is centered on the blocks.

The following are the general dimensions of the dock:

Length over all, feet	525
Breadth over all, feet and inches	126–$2\frac{7}{16}$
between walls, feet	100
Depth over sills, feet	18
of pontoons, feet and inches	17–6
Maximum draught, feet and inches	49–6
Number of pontoons	3
Length of middle pontoons, feet	242
end pontoons, feet and inches	141– $\frac{3}{8}$
walls, feet and inches	395– $\frac{3}{8}$
Total weight of dock, tons	6,865

The dock consists of five portions, and comprises three pontoons as the lifting portion of the dock, and two side walls, which latter, while affording a certain amount of lifting power, primarily serve to give the dock stability and to regulate its descent when the pontoons are submerged. The pontoons themselves are of different sizes and form. The center one is 242 feet long and rectangular in shape, but the rectangular length of two terminal pontoons is only 80 feet, the remainder being finished off in the form of a blunt-nose point or bow. For a length of 55 feet these end pontoons are buoyant, and the remaining length, forming the point proper, is formed by a series of plate and lattice girders of strong construction. Each pontoon has three longitudinal bulk-

heads, the two outer ones being watertight, while the middle one is designedly left with small openings.

This central longitudinal bulkhead is intercostal between the transverse bulkheads, and has two vertical plates, connecting to the first and second intermediate frames by angles. These longitudinal frames are placed 2 feet 6 inches apart, and are of a girder design, each frame calculated to withstand a strain of from 40 to 65 tons load per foot. This construction is carried throughout the entire central portion of all the pontoons, and covers the area required for affording the necessary stability for carrying the heaviest battleships now built. Athwartship bulkheads are introduced every 10 feet, every fifth and sixth being watertight. The side walls are similarly constructed with five transverse bulkheads, and are provided with two gangway openings on each side. These walls are connected to the pontoons by steel castings and fish plates, and secured together by taper pins and bolts.

The operating plant consists of engines, boilers and pumps, which are installed in two walls, each being a separate and complete plant within itself. The main pumps are placed in the bottom of the walls, and are connected by vertical shafting and gearing to engines which are of the compound type. They are furnished with automatic flywheel governors. A notable feature in the governing device of these engines is that the speeds of the pumps can be regulated with a variation of from 310 to 410 while the engine is in motion.

The two side walls are also provided with flying gangways, which are placed at the bow end of the dock, and are hinged so as to swing together. They are provided with a platform and hand railing, which provides a means of passing from one side wall to the other. There are also on the inside of the side walls convenient ladders and stairways to reach the upper and intermediate deck from the deck of the pontoons. Each gangway deck and opening is provided with light swinging hand cranes for handling material from offshore connections or from lighters.

The actual mooring of the dock will be by four chain cables of the stud-link pattern, to which will be attached mushroom

anchors, the handling of which is done by heavy capstans connected to powerful winches; the cables are provided with coil-spring buffers where they make fast to the dock. There are also provided auxiliary winches, fairleads and all the necessary appliances for handling the lines for docking a vessel. The operating valve houses are located on the top deck of each side wall, from which position the entire manipulation in docking a vessel is conducted. Four mechanical side shores, two in each wall, are also operated from these top decks, so that a vessel can be easily and directly centered over the keel blocks.

An important feature of the dock is that any portion of it can be made accessible for repairs or inspection. To reach the bottom of one of the walls, say the port one, it is only necessary to heel the dock to starboard.

In the case of the pontoons, the middle one is made large enough to raise those at the ends out of water. Suppose it is desired to get at the bottom of the middle pontoon: the dock is allowed to float light; men then knock on the tapered pins of the two rows of fishplates which secure this pontoon to the side walls; then the dock is allowed to sink, the middle pontoon floating free, until the lower row of fishplates on the pontoons is level with the upper row on the walls; the pins are then driven in, the dock pumped out, and the middle pontoon is lifted clear of the water. To unlock, the reverse course is followed. The end pontoons are similarly treated. The interior of the walls and pontoons is easily accessible through numerous manholes.

Should a disabled ship draw one or two more feet than the capacity of the dock permits, the dock master would not hesitate to sink the dock the extra depth, as the walls have a minimum freeboard of 4 feet 9 inches. Also, should a ship, from any cause, have a list, the dock could be given the same list within limits, the ship taken in, and the two then brought to an even keel.—"Scientific American."

TEST OF A CENTRIFUGAL PUMP.

The following abstract of a paper entitled "A Filtration Plant at Albany," presented at the Milwaukee Convention of the Amer-

ican Society of Mechanical Engineers by William O. Webber, is from "Engineering News."

The water supply of the City of Albany was augmented in 1873 by taking water from the Hudson River. Owing to the fact that sewage was found in the intake at low-water stages of the river, a new intake was constructed at a point about two miles further up the river and a filtration plant established at that point.

The water is pumped up to this filtration basin by two 24-inch Webber centrifugal pumps, as made by the Lawrence Machine Company, which are directly connected to two 10 and 18 by 10-inch Watertown vertical, cross-compound condensing steam engines. The pumps have disks 42 inches in diameter. These engines are supplied with steam from two Hunter vertical boilers of approximately 120-horsepower each. Vacuum is produced by two Deane 6 and 9 by 12-inch condensing pumps, and the boilers are fed by two Blessing $4\frac{1}{2}$ by 6 by $2\frac{1}{2}$-inch boiler feed pumps. The pumps have a guaranteed capacity of 16,000,000 gallons each per twenty-four hours against 18 feet, or 12,000,000 gallons per twenty-four hours against 24 feet. Upon leaving the pumping station the water passes through a 36-inch Venturi meter, which records the amount of water pumped. A 24-hour test on the No. 2 boiler, pump and engine was made by Allan Hazen, M. Am. Soc. C. E., of New York, and the writer. The drips from the engine were disconnected and showed no leaks of steam. The blow-off from the boiler was disconnected and proved to be perfectly tight. The No. 1 boiler was blank flanged, and a steam pipe led from this No. 1 boiler to an auxiliary pump, which was used to pump the feed water into the weighing tanks. A running start was made with about 3 inches of fire above the grates at 12·30 P. M., Monday, March 26, there being just 13 inches of water in the water glass on the boiler. These conditions were maintained constantly and exceedingly uniform for the next twenty-four hours, ending 12·30 P. M., Tuesday, March 27. The results of these tests are given in the following tabulation:

Duty Trial of Engines and Pumps.

Number of steam cylinders	2
Diameter steam cylinders, inches	10, 18
piston rods, inches	$1\frac{13}{16}$
Stroke, inches	10
Delivery diameter centrifugal pumps, inches	24
Diameter pump disks, inches	42
Initial pressure by gage, pounds	126
Vacuum by gage, inches	24.5
Duration of trial, hours	24
Revolutions per minute	214
Mean effective pressure, high-pressure cylinder, pounds	40.9
low-pressure cylinder, pounds	15.52
Head in feet	20.92
Total water pumped, gallons	13,740,000
Duty per 1,000 pounds feed water, foot pounds	44,574,801
100 pounds dry coal, foot-pounds	40,610,000
Piston speed, feet per minute	355.24
Indicated horsepower	76.16
Efficiency of pumps and engines, per cent	50.5
Feed water per hour, pounds	2,243.5
H.P. condenser and feed pumps	10.48
Dry coal per gross H.P. per hour, pounds	2,843
Water evaporated per gross H.P. per hour from 142.7 degrees to 126 pounds pressure, pounds	25.9
Feed water per hour, condenser and feed pumps, pounds	629
Dry coal per hour, condenser and feed pumps, pounds	6.69
Feed water per hour, main engine, pounds	1,614.5
Duty of main engine alone for 1,000 pounds steam, foot-pounds	61,970,000
100 pounds coal, foot-pounds	56,708,000
Friction, engine and pump, horsepower	10.57
Net efficiency of pump alone, per cent	77

Boiler Test.

Boiler pressures, by gage, pounds	126
Barometer, inches	29.72
Escaping gases, degrees Fahrenheit	299.7
Feed water to economizer, degrees Fahrenheit	82.5
boiler, degrees Fahrenheit	142.7
Moisture in coal, per cent	5
Total refuse, per cent	4.77
Quality of steam, per cent	98.6
Equivalent water evaporated into dry steam from 212 degrees per hour, pounds	2,471
Water evaporated per pound dry coal, pounds	8.98

Equivalent evaporation per pound dry coal from 212 degrees, pounds..	10.032
Equivalent evaporation per pound combustible from 212 degrees, pounds.....	10.535
Efficiency of boiler, per cent.....	69.77

TEST OF A FEED PUMP.

In the following table are given the results of a test published in "Engineering" of a compound direct-acting boiler feed pump constructed by Messrs. J. P. Hall and Sons, Limited of Peterborough, England. The tests were made by Mr. J. Rutherford Blakie, resident engineer at the Penrose Street electric lighting station, Walworth, S. E. The pump has cylinders 6 inches and 9½ inches in diameter by 10½ inches normal stroke, and the pump cylinder was 6¼ inches in diameter. The boiler pressure was 160 pounds per square inch, and the pump was rated to supply 2,000 gallons per hour.

The following are the figures obtained:

Time.	Strokes.	Average strokes per minute.	Water pumped.	Average pumped per stroke.	Condensed steam.	Water pumped.—Condensed steam.	Pressure on delivery per inch.	Stroke of pump.
			lbs.	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*ins.*
No. 1 test.								
9·39 A. M.—9·59.....	700	35	7,329	10.47	73	100.3	172	10⅜
No. 2 test.								
10·04 A. M.—10·24.....	500	25	4,886	9.772	56	87.25	172	10⅜
No. 3 test.								
10·27 A. M.—10·47.....	320	16	3,141	9.81	42	74.78	172	10 7/16

TRIAL OF A TURBO-GENERATOR AFTER TWELVE MONTHS' WORKING.

The report which follows on the test, by Professor Ewing, of a turbo-generator that had been in use some twelve months, is from "Engineering," which says that the report is of especial interest, in view of a charge frequently brought against these prime movers to the effect that though highly economical

when new, they become great steam eaters after six months' work. As will be seen from the figures given below, the consumption of steam per kilowatt-hour did not differ very greatly in Professor Ewing's tests from what it was at the tests made fifteen months previously. It should be borne in mind that the engine in Professor Ewing's tests was driving its own air and circulating pumps, and was supplied with wet steam, whilst at the Newcastle trials of October 27, 1899, dry steam was provided, and the air and circulating pumps independently driven.

REPORT ON TRIALS OF A 500-KILOWATT STEAM TURBO-ALTERNATOR AT THE WORKS OF THE CAMBRIDGE ELECTRIC SUPPLY COMPANY, LIMITED, JANUARY, 1901.

At the request of Messrs. C. A. Parsons & Co., I have made a series of trials of a 500-kilowatt steam turbo-alternator, at the works of the Cambridge Electric Supply Company.

This machine was supplied by Messrs. Parsons to the Cambridge Company, and was erected at the company's station in January, 1900. During the last year it has been doing a large part of the duty of the station. The machine was tested in its place in the station, and under the same conditions in all respects as those which hold in its regular work. The tests are, therefore, specially important as showing the behavior of one of these turbine dynamos under the conditions of daily use, and after it has been in use for a considerable time. The Cambridge Supply Company were good enough to afford all possible facilities for carrying out the trials.

The station log, to which the company's manager and engineer gave me access, shows that the machine began to run on January 20, 1900. By the end of January it had run for ninety-seven hours. In February and March it ran almost daily, taking the heaviest part of the daily load. From the middle of April to September it did duty only from time to time, these being months of light load. In October it ran almost daily. In November a sister machine of the same power was installed, and from that time the two machines were employed to take the load on alternate days.

The machine is a compound turbine of the parallel-flow type running at about 2,700 revolutions per minute, and governed electrically to give constant volts, with its shaft directly coupled to the armature of a four-pole alternator generating 250 ampères at 2,000 volts. The exciter armature is on a prolongation of the same shaft. Steam was supplied at 150 pounds per square inch from a pair of Lancashire boilers, through about 140 feet of a steam pipe, for the most part 6 inches in diameter. The steam was not superheated, and there was no separator, but water which collected in a pocket under a vertical limb of the steam pipe leading to the engine was from time to time blown off. This, however, was insufficient to keep the steam dry, for the velocity of steam in the pipe was too great to allow much of the moisture to be deposited in the pocket. Evidence that the steam was, in fact, wet on admission to the turbine was given when an indicator was applied to record the variation of pressure in each of the successive blasts by which the steam was admitted. This wetness would, of course, affect unfavorably the results of the tests.

The turbine is furnished with a surface condenser, and drives its own air pump and circulating pump (the latter lifting water 12 feet), by means of a shaft carrying a screw wheel which is driven by a worm on the main turbine shaft. The measured consumption of steam therefore includes what is required to drive these auxiliaries.

The discharge from the air pump was delivered, for the purpose of the test, through a two-way valve into tanks which were filled alternately. The discharge into each was continued until the tank was filled up to an overflow lip in a narrow neck, and the valve was then thrown over, to fill the other tank, any overflow from the lip being collected in a can and emptied into the other tank. The time at which each tank in turn was filled was noted to the nearest second, and the times were taken continuously from tank to tank during each run in the trials.

To measure the output of the machine a Kelvin watt balance was employed, which, at the conclusion of the trial, was sealed

up and sent by messenger to Glasgow to have its constant re-determined by the makers, Messrs. Kelvin and White. They reported that a small correction in the original constant had become necessary. The corrected constant determined in this way has been used in the reduction of the results. During each trial the readings of this watt meter were taken regularly every $2\frac{1}{2}$ minutes. Readings were also taken of a Kelvin electrostatic volt meter and an ampère meter. The results of these were in good general agreement with those of the watt meter, but it is the readings of the watt meter which have been accepted as authoritative.

The tanks were calibrated by me after the trials by weighing each with its contents on a standard platform balance. When filled to the overflow lip with water at 75 degrees Fahrenheit, the weight of the contents was:

Tank No. 1, pounds, ...	371.5
2, pounds, ...	369.7
Mean, pounds, ...	370.6

The machine was loaded for the purpose of the tests by discharging its current between iron plates in the river Cam. By varying the immersion of one of the plates the load was caused to vary, in successive trials, from 586 kilowatts (an overload of one-sixth) down to zero.

Preliminary trials at 535 kilowatts and 300 kilowatts were made on January 8th, when the staff of observers, which consisted of my assistants, Messrs. Inglis, Peake, Peel and Sheldrick, with Mr. Wynne, of the Electric Supply Company, were familiarized with their duties. On January 9th the complete series of trials was made without a break, the load being varied from one trial to the next without stopping the machine.

On that day, January 9th, the machine started at 7·40 A. M., and a load of 520 kilowatts was applied at 8·10 A. M. The test was continued under this load until 10 A. M. The following figures relate to the last thirty tanks during the hour from 9 to 10:

Time of filling ten tanks. (3,706 pounds of steam.) Minutes.	Seconds.	Mean output in kilowatts.
17	2,	514
17	5,	517
17	8,	518

Taking the last ten tanks (after the machine had warmed to its work), the air pump discharge is 3,706 pounds in 0.2856 hours, or 12,970 pounds per hour. This is at the rate of $\frac{12,970}{518}$, or 25.0 pounds of steam per electrical unit of effective output.

The load was then increased to 586 kilowatts, and twenty tanks of air-pump discharge were measured. The time per tank (ranging from 1 minute 35 seconds to 1 minute 32 seconds) was sufficient, but not much more than sufficient, to let one tank empty while the other was filling. The following are the times for each ten tanks, with the output:

Time of filling ten tanks. (3,706 pounds of steam.)	Pounds per hour.	Mean output in kilowatts.
15 minutes 27 seconds,	14,390	587
15 minutes 35 seconds,	14,260	584

The mean for the whole of this run is 14,320 pounds per hour, with an output of 586 kilowatts, or 24.4 pounds per electrical unit of effective output.

The load was then reduced to 273½ kilowatts, and fifteen tanks were measured, taking 43 minutes 7 seconds; this is at the rate of 7,730 pounds per hour, or 28.3 pounds per electrical unit of effective output. The load was then further reduced to 160½ kilowatts, and ten tanks were measured, taking 41 minutes 50 seconds; this is at the rate of 5,320 pounds per hour, or 33.1 pounds per electrical unit.

Finally, the load was reduced to zero, the exciter, however, being kept at work so that the volts of the dynamo were maintained. It then took 24 minutes 12 seconds to fill two tanks, which corresponds to a consumption of 1,850 pounds per hour.

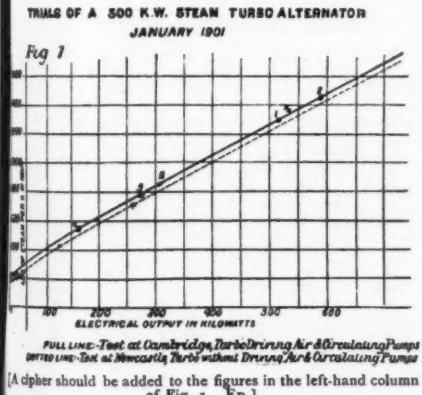
In the preliminary trial of the previous day, with an output of

535 kilowatts the consumption of steam was at the rate of 13,350 pounds per hour, and with an output of 300 kilowatts the consumption of steam was at the rate of 8,270 pounds per hour.

The following are collected results as to the consumption of steam at various grades of output, including the preliminary as well as the final trials:

Trial No.		Effective electrical output in kilowatts.	Consumption of steam.	
			Pounds per hour.	Pounds per unit.
Trials of January 9.....	1	518	12,970	25
	2	586	14,320	24.4
	3	273½	7,730	28.3
	4	160½	5,320	33.1
	5	0	1,850	...
Preliminary trials of January 8.....	A	535	13,350	25
	B	300	8,270	27.6

The relation of the consumption of steam in pounds per hour to the output in kilowatts is shown in the accompanying curve.


TRIALS OF A 500 K.W. STEAM TURBO ALTERNATOR
JANUARY 1901
Fig 1
ELECTRICAL OUTPUT IN KILOWATTS
FULL LINE-Test at Cambridge Turbo Driving Air & Circulating Pumps
DOTTED LINE-Test at Newcastle Turbo without Driving Air & Circulating Pumps

[A cipher should be added to the figures in the left-hand column of Fig. 1. Ed.]

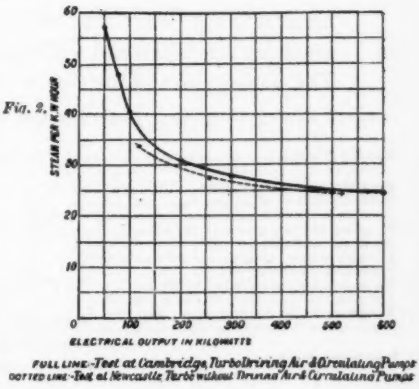


Fig. 2.
STEAM PER K.W. HOUR
ELECTRICAL OUTPUT IN KILOWATTS
FULL LINE-Test at Cambridge Turbo Driving Air & Circulating Pumps
DOTTED LINE-Test at Newcastle Turbo without Driving Air & Circulating Pumps

It will be observed that the points representing the various trials lie well on a smooth line which is nearly straight. By measurement from the line so drawn the following figures are obtained:

Output in kilowatts.	Consumption of steam.	
	Pounds per hour.	Pounds per unit.
600	14,600	24.3
500	12,500	25
400	10,400	26
300	8,300	27.7
200	6,140	30.7
100	4,020	40.2
75	3,550	47.7
50	2,840	56.8
0	1,850	...

These figures give most satisfactory evidence that the machine working under the conditions of every-day use retains its character as a highly efficient electrical generator. The efficiency is well maintained when the load is reduced even to one-fourth or less of its normal amount.

Particulars of the pressures, temperatures, etc., in the various trials are given in the Table below. The figures stated are, in each case, means taken from logs which were kept throughout the trials.

At the end of the trials on January 9, after the machine had been running under load for five hours the temperature of the armature was taken and was found to be 118 degrees Fahrenheit. The temperature of the engine room was 77 degrees Fahrenheit.

TABLE GIVING PRESSURES, TEMPERATURES, &C., DURING TRIALS OF TURBO-ALTERNATOR.

Number of trial	1	2	3	4	5	A	B
Electrical output in kilowatts	518	586	273½	160½	...	535	300
Volts at terminals of generator	2,100	2,150	2,250	2,290	2,280	2,120	2,110
Speed in revolutions per minute	2,670	2,740	2,630	2,590	2,580	2,880	2,800
Air pump discharge, pounds per hour	12,970	1,320	7,730	5,320	1,850	13,350	8,270
Air pump discharge, pounds per kw. per hour	25	24.4	28.3	33.1	...	25	27.6
Pressure at stop valve, pounds per square inch	148	145	151	151	121	145	150
Vacuum in condenser, inches	27.8	27.9	28.2	28.3	28.3	26.6	27.6
Vacuum in turbine cylinder, inches	25.7	25.4	27.2	27.8	28.1	25.1	26.2
Temperature of air pump discharge, deg. F.	74	76	57½	56	54	90	68
Temperature of circulating water, inlet, deg. F.	40	40	38	39	36	41	39
Temperature of circulating water, outlet, deg. F.	71	72½	60	57	46	91	71
Barometer, inches	29.93					29.99	

The following copy of tests of the same machine made in Newcastle at the makers' works by the Cambridge Company's engineer, before the machine was delivered, has been supplied to me:

500-KILOWATT CAMBRIDGE MACHINE, No. 728.—TESTS MADE OCTOBER 27, 1899, BY CAMBRIDGE ELECTRIC SUPPLY COMPANY'S ENGINEER.

Boiler pressure, pounds	139	145	140
Vacuum, inches	24½	26⅝	27⅝
Barometer, inches	29.6	29.6	29.6
Water per hour, pounds	12,675	7,029	4,180
Average kilowatts	526.4	256.1	124
Average volts	2,015	2,115	2,015
Average speed	2,750	2,750	2,700
Pounds per kilowatt-hour	24.1	27.5	33.7

I am informed that these tests were made with dry steam, and the engine was not driving its own pumps. Considering the altered conditions in these two respects, I am of the opinion that the results of the present trials show that there has been no deterioration due to wear. J. A. EWING.

January 30, 1901.

It was unfortunately impossible at Cambridge to conform to the identical conditions of the makers' tests, and to run the turbine without driving the combined pumps. The original consumption guaranteed by the makers was to include that absorbed by the pumps, and in dispensing with this the makers reduced their guarantee at full load by 1 pound of steam per kilowatt.

The turbo-alternator, to which the above tests relate, was built from designs made in 1897. Since that date a new type has been supplied, and tests made by Mr. Hamilton Kilgour for the Cheltenham Corporation, and Mr. F. G. Holden for the Scarborough Electric Supply Company, of two sets of 500 kilowatts output are given below. The difference in favor of the former is due to its being of a higher speed, viz: for 100 periodicity against 80 periodicity in the latter case.

TESTS OF 500-KILOWATT TURBO-ALTERNATORS (RECENT TYPE).

—	Cheltenham Corporation tests by Mr. H. Kilgour.		Scarborough, Mr. F. G. Holden.	
Machine number	772	772	770	770
Stop-valve pressure	130	129	126	128
Vacuum	26.7	27.2	26.8	27.65
Load in kilowatts	553.17	275.8	529	258
Water per hour	21.7	26.2	22.7	26.4
Volts	2,120	2,000	1,990	2,000
Speed	3,000	3,030	2,400	2,500
Superheat	Nil	Nil	Nil	Nil

THE PERFORMANCE OF FRENCH SUBMARINE TORPEDO BOATS.

During the past three or four months the French have made a number of tests of their submarine boats to determine their endurance, their habitability and their effectiveness as weapons of offense.

The *Narval* was provisioned the latter part of May at Cherbourg and started on a 48-hour endurance test, accompanied by the seagoing torpedo boat *Zouave*. The sea was rough, in consequence of which she put into St. Malo, after having run for 41 consecutive hours, during which she made several plunges.

She left St. Malo the next day, having recharged her accumulators with her own engines, and having enough oil left for several hours.

Subsequently, she made a submerged test, lasting 12 hours, using only her electric motors for propulsion. After this trial the crew was thoroughly exhausted on account of the foul air they had to breathe, which is ascribed to the emanations of the accumulators. Experiments are now being conducted with a view to overcoming this condition, Dr. Gibrat having prepared a tablet with which the men are to moisten their lips and their nostrils. This was to have been tried on the *Morse* during a test of 16 hours duration, but the results have not been made public.

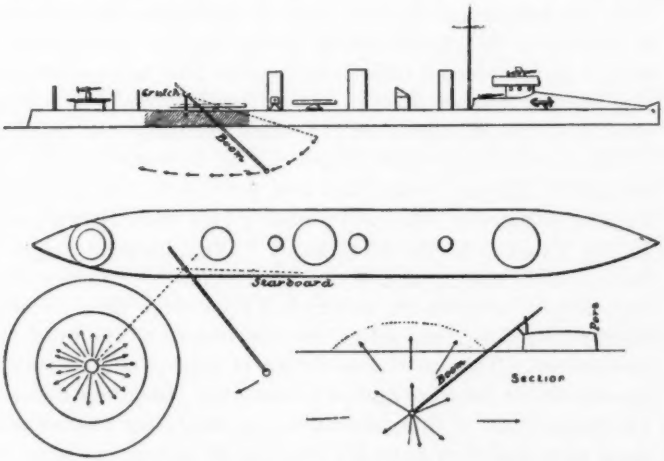
The most sensational performance was that reported of the *Gustave Zédé*, which is said to have torpedoed the battleship *Jauréguiberry* in the harbor of Ajaccio on the 3d of July. The circumstances were as follows: The *Zédé* left Toulon in tow, and when a few miles off Ajaccio cast off from the tug, and proceeded submerged into the harbor, where were at anchor several vessels of one of the squadrons engaged in the maneuvers. After discharging her torpedo, she rose to the surface, to the astonishment of the vessels in harbor. This is the account given in the French papers. "The Engineer" (London) says that, by the rules laid down for the maneuvers, Ajaccio was a port that was not subject to attack, and, therefore, the fleet would not be on the lookout for such craft; and further, that the *Zédé* was seen, and that the *Jauréguiberry*, which was getting under way, had to change her course in order to avoid running her down.

Next in order was an attempt of the *Morse* to torpedo the gunboat *Cocyte*. The *Morse*, which was at Cherbourg, was ordered to proceed to Havre and attack the *Cocyte*. She was convoyed by a tug until within sight of Havre, when she dived about 8 miles from the shore. The *Cocyte* was apparently aware of her approach, for she had her searchlight going, and, it appears, picked her up when about 400 yards away. The *Morse* did not succeed in her attack, the reason assigned being the state of the sea.

SUBMARINE BOAT DESTROYERS.

The English have for some time been carrying out experiments on the *Starfish* with an apparatus designed to destroy submarine boats. The arrangement is thus described by "The Engineer":

In the present state of the science a submarine attacking a ship is bound to come to the surface to take bearings, or else to



betray her presence with an optic tube or periscope. With this new invention—evolved in the *Vernon* and tried recently before the Lords of the Admiralty—the sighting of a submarine entails her almost certain destruction. Sighting is now practically certain. It is not to the public benefit that the means which will

be employed should be stated, for the principle has other and varied uses. We will pass on, therefore, to a brief description of the means of destruction. The shaded part of the hull of the destroyer in the figure indicates plates that have been strengthened on the starboard side. Above these is a crutch upon which a boom, 42 feet long, works. This boom normally stows inboard and forward. At the far end of it a charge of explosive is carried, explodable as are all spar torpedoes. On going into action the boom is slung out well forward, and immersed in the water at the proper moment. This immersion carries the boom end downward and aft, and it is exploded directly the submarine is passed. The speed of the destroyer carries her past the center of the explosion before its full effects reach her, though in any case destroyers are too light and "cork-like" to be seriously affected. The submarine down in the water is in a different case. It experiences the full force of the terrific concussion. Within from 60 feet to 100 feet or more of the center of explosion, according to the charge employed, the sides of the submarine should be compressed sufficiently to cause fatal leaks, while even at a greater distance stability should be destroyed. It will be seen, then, that the equivalent to a "miss" is hardly to be expected.

The single experiment carried out at Portsmouth was not enough to indicate exactly the best position for the boom, and the first boats to be fitted will probably vary somewhat between having it on the quarter or right aft. The additional weight of the boom is slight; in the case of the *Starfish*, the destroyer experimentally fitted, the weight has been more than compensated for by fitting her with aluminum instead of the usual torpedo tubes. This particular device is merely one of several equally simple remedies against submarines. That the Admiralty has busied itself in this connection is a matter for considerably more congratulation than the building of submarine boats for the British navy.

WATER-TUBE BOILERS FOR BRITISH SHIPS.

Although the information given on page 375 of the last number of the JOURNAL was the best then obtainable regarding the

decision of the Admiralty on the type of boiler that was to be used in the several ships mentioned, it was found that, when firms that had contracts were approached regarding the substitution of other boilers for the Belleville boilers that had been contracted for, the conditions demanded were such that it was decided to retain the Belleville in the *Prince of Wales*, *Donegal* and *Cumberland;* to put Babcock and Wilcox in the *Queen* and *Challenger*, and in the *Hermes* after the removal of her Belleville boilers; to put Niclausse in the *Suffolk*, *Berwick* and *Fantome*, the Belleville of the *Fantome* to go in the *Merlin;* Dürr boilers in the *Encounter* and *Medusa*, and Yarrow in the *Medea*, the boilers in the two latter supplanting Scotch boilers. Upon completion of the new boilers, competitive trials are to be made between the *Hermes* and the sister ship *Hyacinth*, which has Belleville boilers, and between the *Medea* and *Medusa*, in order to determine, in each case, the better type of boiler.

EXPLOSION ON H. M. S. *DARING*.

A serious explosion occurred June 10 on board the torpedo destroyer *Daring*, resulting in one man being killed and four others injured. During the day the vessel was engaged towing a target for the *Narcissus* gunnery ship. As the vessel was returning into harbor after practice, a loud report was heard, and dense volumes of fire and smoke were seen issuing from the forward smoke pipe and the forward fire-room hatch. Subsequent examination showed that a tube in one of her boilers had pulled out of the lower drum. The boilers had recently been overhauled and retubed.

SHIPS.

UNITED STATES.

Designs for New Battleships.—The Board on Construction has so far completed its consideration of this question as to have submitted a report to the Navy Department. There is, however, a difference of opinion on the question of battery. The reports follow:

Majority Report.

NAVY DEPARTMENT, BOARD ON CONSTRUCTION,
WASHINGTON, *July 12, 1901.*

SIR: 1. Complying with the instructions contained in the Department's letter No. 1826–01 of March 6, 1901, the Board on Construction has given careful consideration to the subject of the design of a seagoing battleship, of which plans and specifications are to be submitted to Congress in December next, as required by law.

2. The Board, being unable to reach a unanimous agreement concerning the armament and its disposition, makes this preliminary report for the information of the Department in order that instructions may be issued which will permit progress upon some definite design at an early date.

3. The majority of the Board, composed of the Chief of the Bureau of Ordnance, the Engineer-in-Chief, and the Chief Constructor, recommend for adoption a design of which the following are the important particulars, the general arrangements being shown upon the accompanying tracing.

4. The Chief Intelligence Officer suggested the scheme now recommended by the minority, but has never seen nor had an opportunity to consider the design of the majority.

5. The conclusions of the Board have been reached after a consideration and comparison of the designs of battleships already built, and also of about seven or eight sketch designs

illustrating various types of armament, gun mounting, and armored protection, all of which will be furnished to the Department if required.

STATEMENT OF PARTICULARS OF SEAGOING BATTLESHIP FOR THE UNITED STATES NAVY.

Length, feet and inches	450– 0
Beam, feet and inches	76– 3
Mean draught at trial displacement, feet and inches	24– 6
Displacement at trial, tons	15,560

Preliminary estimated weights:

	Tons.
Hull, fittings and protective deck	6,869
Armament	974
Two-thirds ammunition and ordnance stores	445
Engineer's weights	1,820
Reserve feed	66
Protection	3,676
Equipment and two-thirds equipment stores	310
Outfit and two-thirds stores	400
Coal, on trial	1,000
Total	15,560

Total coal capacity, about, tons	2,000
Deep-load displacement, tons	16,900
Deep-load draught, feet and inches	26– 4
Speed, knots	19
Indicated horsepower	20,000

Battery.—Four 12-inch guns in 10 inch armored turrets.

Twenty 7-inch guns in casemates.

(Eight of these 7-inch guns are individually enclosed by armor —four on the upper deck and four on the gun deck—firing ahead and astern. The remaining twelve guns are located in the central casemate battery of the gun deck, separated by armored bulkheads into groups of four—two guns on each side of the ship—which may be further subdivided as the details of the plans progress.)

Twenty 14-pounder (3-inch) guns, of which twelve are protected by 2-inch side armor.

Armor.—A complete armor belt 10 inches thick throughout

the machinery space, 9 inches in way of magazine space, tapering to 4 inches forward and aft.

Second belt, from protective to gun deck, 6 inches thick.

Casemate armor on gun deck, 7 inches thick.

Casemates on upper deck, 7 inches thick.

Twelve-inch turrets in barbettes, 10 inches thick.

Remarks.—The essential difference between the majority and minority is in the battery, the recommendations being as follows:

MAJORITY.	MINORITY.
Four 12-inch guns in 10-inch armored turrets.	Four 12-inch guns in two turrets.
Twenty 7-inch guns in casemates. (Eight of these 7-inch guns are individually enclosed by armor—four on the upper deck and four on the gun deck—firing ahead and astern. The remaining twelve guns are located in the central casemate battery of the gun deck, separated by armored bulkheads into groups of four—two on each side of the ship—which may be further subdivided as the details of the plans progress.)	Twelve 8-inch guns in six turrets, two of which are superposed on the 12-inch turrets and two on each beam. Twelve 6-inch guns in casemates on the gun deck.
Twenty 14-pounder (3-inch) guns, of which twelve are protected by 2-inch side armor.	Eight 14-pounder (3-inch) guns.

6. Before proceeding to discuss the points of difference in regard to the battery and its mounting, the Board desires to point out, first, the final result of these differences upon the general design. All other essential features of the design being the same (except the battery), the majority ship can be built upon a trial displacement of 15,560 tons and a corresponding mean draught of 24 feet 6 inches. The minority ship will require, owing to greater weight of armor to protect a battery of the same weight, a displacement of 15,860 tons, and the most efficient method of obtaining this greater carrying capacity will be to add to the draught of water, making the mean trial draught 24 feet 11 inches, or 5 inches greater than the draught of the majority's design. This in itself is an objectionable feature.

7. The principal points of difference between the battery plan

of the majority and minority are that the majority do not recommend the further use of superposed turrets, and they recommend a uniform caliber of 7 inches for what may be termed the *auxiliary* battery, in preference to a mixed battery of 8-inch and 6-inch guns. The majority simplify the construction of the ship and the mounting of the battery by reducing the number of turrets (counting each double turret as two) from eight to two, and mounting all the 7-inch guns in armored casemates.

8. The majority, in adopting this recommendation, have given careful consideration to other schemes involving the use of the 8-inch gun in lieu of the 7-inch, or a mixed battery of 8-inch and 6-inch, and find that the 8-inch gun, with mount, as now designed, weighing 29 tons, the gun being 28½ feet in length, is beyond the size which can be efficiently mounted singly in broadside.

9. The majority, after giving careful consideration to all our previous battleship designs, recognized in them several features which were capable of improvement in connection with the auxiliary guns. Through the recent development of a very powerful 7-inch gun, we are enabled, in the opinion of the majority, to make a decided advance on previous designs. It is possible, in the first place, to establish for the auxiliary guns a uniform caliber and mounting instead of a heterogeneous battery composed of two different calibers, each differently mounted. It is possible, in the second place, to mount the auxiliary guns singly in broadside, gaining marked advantages as regards rapidity of fire and simplicity and ease of ammunition supply and avoiding the numerous practical objections to the mounting of guns in turrets, which are generally recognized, and were brought particularly to the attention of our officers who saw active service during the Spanish-American war.

10. A comparison of muzzle energy and weight of metal fired in a minute is appended, which shows from this point of view that the design of the majority is appreciably superior, and it has, in addition, many advantages which cannot be reduced to calculation, which were powerful with the majority in causing them to reach their conclusions.

11. The allegation has been made that by mounting an important portion of the battery in casemates a greater proportion is thereby liable to be disabled by a single well-placed shot than if the guns are mounted in turrets as in the minority's plan. While this statement is generally admitted in principle, the majority claim that in this respect their design is fully equal to that of the minority when due consideration is given to the fact that the minority, by the use of the superposed turret, exposes four guns to disablement by a single shot, and by the mounting of the twelve 6-inch guns in a single casemate renders them *all* liable to be placed out of action by a single large shell charged with high explosive.

12. In this connection the majority desire to repeat what is indicated in the general statement of particulars, that there is greater subdivision of the battery by armored protection than in the minority's plan. The minority expose four of their heaviest guns in one turret, whereas the majority's design has the 12-inch guns in turrets (two in each), eight of the 7-inch guns are individually enclosed in armor—four firing forward and four firing aft—and the remaining twelve 7-inch guns are divided into three groups, separated by armor, and which it is proposed to further subdivide as far as possible in the development of the plans.

13. The majority claim a very important advantage over the minority's plan in providing for twenty 14-pounder (3-inch) guns, as against eight. In increasing the caliber and amount of the auxiliary battery of 8-inch and 6-inch guns the minority have seriously affected the efficiency of their ship by the very great reduction in the number of the secondary battery, which is enforced by the decrease of available positions owing to the great sweep of the turret guns.

14. In proposing the 7-inch gun the majority call attention to the fact that the tendency abroad is to increase the thickness of casemate armor and of what may be termed the light armor generally, to such a degree that it cannot be perforated at battle range by the 6-inch gun; hence the necessity of a more effective rapid-firing gun. The 7-inch, having the essential features of such a gun in its style of mounting, breech mechanism and

energy, seems, therefore, a most appropriate weapon, and the latest information from abroad indicates a tendency on the part of other nations to follow in this direction, the British having developed a 7½-inch rapid-firing gun, and the Germans a 6.69-inch (17 c. m.) gun.

15. The minority lay much stress upon the desirability of retaining the 8-inch gun on account of its popularity during the Spanish-American war, to which the majority reply that had the modern 6-inch or 7-inch gun then been in service it would have been found more efficient than were the 8-inch guns then in use.

16. The new 7-inch gun weighs 13.3 tons and the old 8-inch gun 13.1 tons. The muzzle energy of the 7-inch is 9,225 foot-tons, the muzzle energy of the old 8-inch being 7,498 foot-tons, showing that the new 7-inch gun is a more powerful weapon than the 8-inch guns used during the Spanish-American war, and its type of mounting and breech mechanism give it a decided advantage in ease of manipulation and rapidity of fire.

17. At the battle of Manila Bay the *Olympia*, which carried four 8-inch guns in two turrets (all of which could be and were fired on the same side of the vessel), only fired thirty-six rounds, or 8.5 rounds per gun, while the *Boston*, which had but two 8-inch guns, not in turrets, fired forty-eight rounds, or twenty-four rounds per gun (three times as many per gun as the *Olympia*); and the *Baltimore*, which had four 8-inch guns not in turrets, but only two of which could be fired on one side, fired seventy-three rounds, or 36.5 rounds per gun, showing plainly what a disadvantage guns in pairs in turrets are at as compared with those not in turrets and independently mounted.

18. The large number of rounds fired by the *Baltimore* is due to the fact that when the engagement was reopened after the fleet withdrew to take stock of ammunition, she was considerably in advance of the fleet, and consequently had an opportunity to do more firing than the other vessels, but she may properly be credited with the same rate of firing as the *Boston*.

19. At the battle of Santiago 319 8-inch shells were fired, the probability being that eighteen guns of this caliber were engaged,

in which case the average would be but 17.6 rounds per gun, all these guns being mounted in pairs in turrets. Of the 319 8-inch projectiles fired at Santiago, there were but thirteen hits, according to the report of the board which examined the wrecks of the Spanish vessels, or but 4.07 per cent., and the hits being a fraction of one for each gun.

20. If the same ratio of hits is applied to the number of 8-inch shell fired at Manila, the total number of hits would be 6.38, or less than one hit per gun, hence no great amount of accuracy or rapidity of fire can be credited to the guns of this caliber either at Manila or Santiago. The probability is that the 8-inch guns became popular on account of their great range, with a comparatively flat trajectory, but the proposed 7-inch gun far exceeds the 8-inch guns now in the service in the extent of its range and the flatness of its trajectory for a given distance.

21. The 8-inch is not a quick-firing gun in the generally accepted sense of the term. It has not sufficient energy to penetrate heavy armor at battle range, and has an excess of power for use against lighter armor, and on this account the majority propose the 7-inch gun as more suitable for the intermediate caliber. They believe that the greatest execution in battle will be done by rapid-firing guns of medium caliber, such as they herein recommend.

22. Uniformity of caliber, simplicity of mounting, separation of guns, giving independent action to each, are features of great importance, to which the majority have given special attention in the preparation of their plan, which presents a vessel more powerful than any yet built or projected by any power.

23. During the Spanish-American war there was a general condemnation of turrets as being detrimental to efficient gun service. The heat, lack of ventilation, contracted spaces, and great difficulty of seeing the enemy were commented upon at great length by officers who served in turrets.

24. The majority submit the following comparison, by muzzle energy and weight of metal thrown in one minute, of the guns comprising the main batteries of the two plans under consideration, omitting the 12-inch guns, which are the same in both cases:

This comparison is based upon the supposition that—

Eight-inch guns will be fired at the rate of 1.2 rounds per minute.

Seven-inch guns will be fired at the rate of 2.5 rounds per minute.

Six-inch guns will be fired at the rate of 3.5 rounds per minute.

Muzzle energy of 8-inch guns, 13,602 foot-tons; muzzle energy in one minute, 16,322 foot-tons.

Muzzle energy of 7-inch guns, 9,225 foot-tons; muzzle energy in one minute, 23,062 foot-tons.

Muzzle energy of 6-inch guns, 5,838 foot-tons; muzzle energy in one minute, 20,433 foot-tons.

Weight of 8-inch projectile, 250 pounds; weight of metal thrown in one minute, 300 pounds.

Weight of 7-inch projectile, 165 pounds; weight of metal thrown in one minute, 412.5 pounds.

Weight of 6-inch projectile, 100 pounds; weight of metal thrown in one minute, 350 pounds.

Comparison.—

Majority plan, twenty 7-inch guns:

Broadside fire, 230,620 foot-tons muzzle energy per minute from each broadside.

Broadside fire, 4,125 pounds metal per minute from each broadside.

Minority plan, twelve 8-inch and twelve 6-inch guns:

Broadside fire, 253,174 foot-tons muzzle energy per minute from one broadside only.

Broadside fire, 187,882 foot-tons muzzle energy per minute from other broadside.

Broadside fire, 4,500 pounds metal per minute from one broadside only.

Broadside fire, 3,300 pounds metal per minute from other broadside.

All main battery guns except 12-inch:

Majority plan, 461,240 foot-tons muzzle energy in one minute.

Minority plan, 441,060 foot-tons muzzle energy in one minute.

Majority plan, 8,250 pounds metal in one minute.

Minority plan, 7,800 pounds metal in one minute.

The minority lay much stress upon the strength of end fire, as provided for in their plan, which the majority concede to be very heavy; but it may be remarked that as the chief strength of a modern battleship's battery is in its broadside and not in its end fire, there is every probability that naval battles will, in the future as in the past, be fought broadside to broadside, rather than end on. The minority plan gives two more guns for end fire than does the majority plan; that is, it gives six 8-inch as against four 7-inch, but as the latter are proposed to be mounted separately, having independent action, the majority believe they will prove as efficient as the six 8-inch guns in three turrets proposed by the minority.

Respectfully,

CHARLES O'NEIL,
Chief of Bureau of Ordnance, President of Board.
GEO. W. MELVILLE,
Engineer in Chief, U. S. N.,
Chief of Bureau of Steam Engineering, Member.
(See minority report),
Chief of Bureau of Equipment, Member.
F. T. BOWLES,
Chief Constructor, U. S. N.,
Chief of Bureau of Construction and Repair, Member.
(See minority report),
Chief Intelligence Officer, Member.

THE SECRETARY OF THE NAVY.

BATTERIES PROPOSED FOR THE NEW BATTLESHIPS.

MINORITY STATEMENT.

DEPARTMENT OF THE NAVY, BUREAU OF EQUIPMENT,
WASHINGTON, D. C., *July 19, 1901.*

1. The Board on Construction having agreed to present to the Department a plan of a battery for a battleship, with explanation and argument, approved by the majority of the Board and the same approved by the minority of the Board, each separate and complete, without examination or criticism of the minority plan

by the majority, and vice versa, the following is respectfully submitted:

2. It is requested that if the statements of the majority in any way conflict with the statements herewith, I may have an opportunity to criticize them.

3. The final vote of the Board on the several plans presented was taken during the absence of the junior member, Capt. C. D. Sigsbee, U. S. N. As, however, the plan I herewith present was submitted by Captain Sigsbee after he had examined all other plans considered by the Board, it is fair to presume had he been present he would have voted with the minority.

4. Attention is called to a minority report made by me May 25, 1900, on the armament of battleships. Much of the discussion in that paper is applicable to the subject under consideration, and I therefore forward a copy herewith marked "A." As stated then, I believe the problem is largely a tactical one, and should, therefore, be determined by line officers.

5. *Illustration.*—Accompanying this statement is a lithographic illustration of the batteries of five (5) different types of battleships:

No. 1 represents a class of battleship recommended by all the members of the Board on Construction, except myself, a little more than one year ago. This plan, with its graphic representation below, fully indicates the disposition, number, and size of guns, their arc of fire, etc.

No. 2 represents a class of battleship recommended by me at the same time and urged in the minority report above referred to. The main difference between the two is the disposition of the 8-inch gun turrets. No. 1 is without superposed turrets, but has four 8-inch turrets disposed in the form of a quadrilateral, as in the *Oregon*, *Indiana*, *Massachusetts* and *Iowa*. No. 2 has the same number of 8-inch turrets, but two of them are superposed on the 12-inch turrets. These two designs were submitted by you to a Board of thirteen officers, with the result that a recommendation was made, signed by twelve out of the thirteen, that three ships of No. 2 class be built and two of No. 1. It appears proper to add here that this Board included the five members of

the Board on Construction, in which the vote stood 4 to 1 in favor of No. 1. The first vote of the large Board, however, stood seven in favor of No. 2, five in favor of No. 1, and one in favor of some of each type.

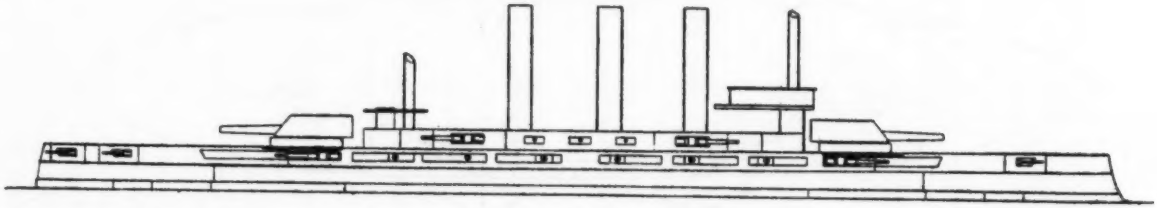
6. As the contracts for the construction of the two classes of battleships represented in No. 1 and No. 2 provided for a change of battery, if desired, within six months after the signature thereof, the Chief of Bureau of Ordnance submitted to the Department a further design of a battery for a battleship, represented in No. 3. Briefly, this design consisted in removing the waist turrets from No. 2 and installing a battery of sixteen 6-inch guns on two open decks protected by casemate armor, between and in addition to the four 12-inch and four 8-inch guns in the main and superposed turrets.

7. You then submitted to a new Board, composed of twelve officers, the selection of the best of the three types represented by Nos. 1, 2 and 3, for the five battleships under construction. This Board was made up of the Board on Construction and seven other officers. It was the same Board, above referred to, of thirteen, with the following exceptions, viz: Rear Admiral Rodgers was replaced by Rear Admiral Evans, Naval Constructor Taylor was replaced by Naval Constructor Woodward, and Captain Brownson was absent.

The first vote of the Board developed the fact that there was not a majority in favor of any one of the three types submitted. On the first vote four favored No. 1 and six No. 3. I voted for No. 3, although I had been the advocate of No. 2, and had been upheld by the majority of the first special Board. It was my desire, however, to have all five ships alike, for tactical reasons, and I considered that type 3, which preserved the superposed turrets, was a fair compromise. It became evident, however, that the Board strongly favored the 8-inch gun and would not submit to a reduction in caliber. After discussion the Board eventually voted 10 to 2 in favor of type 2, and this type is now under construction and known as the *Virginia* class.

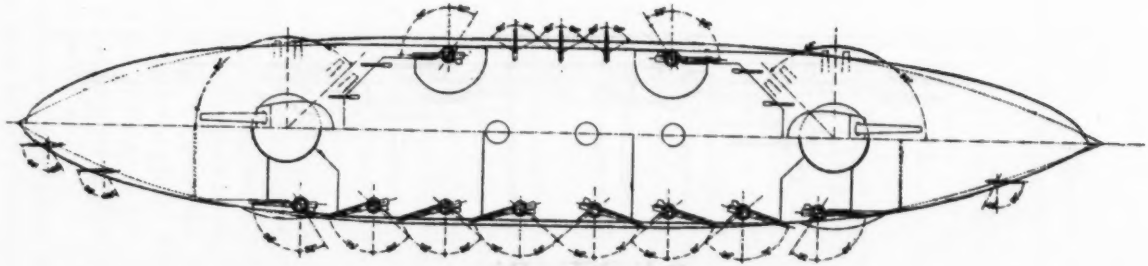
It is proper to add in this connection that of the vote above

NUMBER 4.

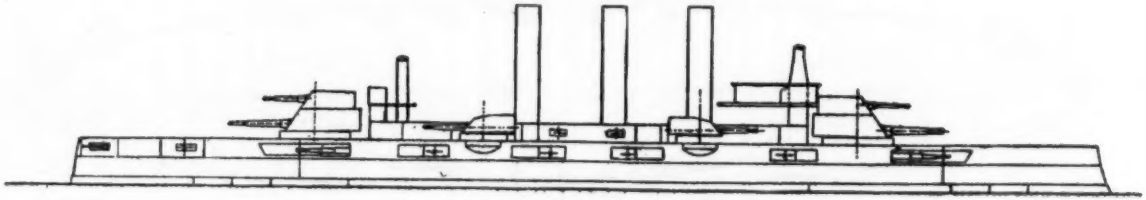


MAIN BATTERY
4—12 inch
20—7 "

SECONDARY BATTERY
20—3 inch

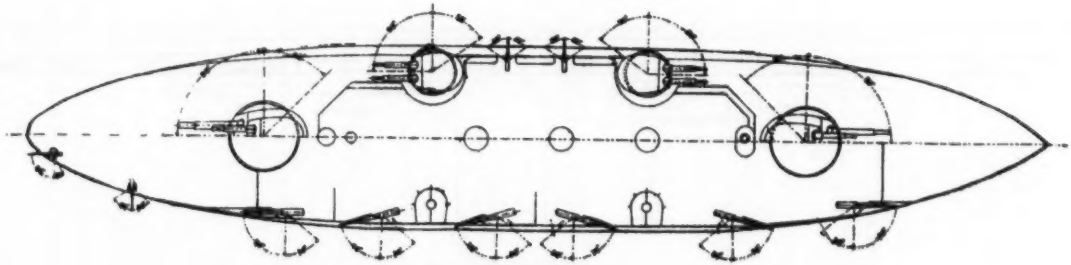


NUMBER 5.



MAIN BATTERY
4—12 inch
12—8 "
12—6 "

SECONDARY BATTERY
8—3 inch



referred to, some members of the Board continued to favor type 1, but accepted type 2 as a compromise in order to prevent the acceptance of type 3.

This brief account of the thorough and painstaking efforts made to ascertain the opinions of the service as to the best type of battleship appears necessary in order to fully understand the new types now placed before you.

8. The plans now presented for your consideration are represented in No. 4 and No. 5; No. 4 by the majority and No. 5 by the minority.

No. 4 has no 8-inch guns, and but two turrets, in which are located four 12-inch guns. Her battery is made up of four 12-inch guns and twenty 7-inch guns. The latter are disposed as follows: Sixteen on the main deck behind casemate armor, arranged largely in accordance with the battery on an old frigate's gun deck. On the deck above at the corners of the superstructure are installed four more 7-inch guns for the purpose of increasing the fire ahead and astern.

Especial attention is called to the general resemblance between this type and the type proposed in No. 3, the difference being that the 8-inch guns and superposed turrets of No. 3 are taken away and, together with the sixteen 6-inch guns, are replaced by twenty 7-inch guns. The absence of turret protection and the reduction in caliber are marked features of No. 4 design, to which officers generally have heretofore shown a marked disapproval.

9. Type No. 5 is a combination of No. 1 and No. 2, both of which, as already stated, have been highly favored in the past. In addition to the usual two 12-inch turrets it has two 8-inch turrets, superposed, and four additional 8-inch turrets arranged in the form of a quadrilateral, as in type No. 1. There are in addition on the main deck twelve 6-inch rapid-fire guns. The battery of No. 5 is therefore made up of the following:

Four 12-inch guns, 12 8-inch guns, 12 6-inch guns in place of 4 12-inch guns, and 20 7-inch guns in type No. 4.

All of the 12-inch and 8-inch guns are protected by turrets, in accordance with the present almost universal foreign practice.

10. Below figures No. 4 and No. 5 are graphically represented the following:

First. The energy of the fire of the two types of ships recommended, when engaged on one side and on both sides, computed in foot-tons for one minute and represented in pink [by hatching]. *In these diagrams the muzzle energy of the 12-inch guns is omitted, as they are common to both ships.*

Second. The arcs of fire of all of the guns in both types.

Before considering the details of these two types your attention is invited to a careful scrutiny of the amount of area in the two pink diagrams, which are correct for certain assumed rates of fire as explained hereafter.

Especial attention is called to the fact that in type 4 the maximum broadside fire of the 7-inch battery extends over an arc of only 64 degrees, with an average muzzle energy of 230,620 foot-tons over that arc, while in type 5 it extends over an arc of 90 degrees, with an average muzzle energy of 253,174 foot-tons, both vessels assumed to be engaged on one side only.

Especial attention is further called to the fact that the average muzzle energy throughout the entire arc of fire for the battery of type 4 is 158,619 foot-tons, while for type 5 it is 190,120 foot-tons when engaged on one side only, and 173,760 foot-tons when engaged on both sides.

The best naval tacticians believe that naval engagements of the future will present few, if any, instances of a single ship being engaged on both sides. If two ships are pitted against one, it is much more advantageous for these two to be on one side and prevent their single enemy from using all her guns.

In addition, if the two ships are in formation it would hardly be possible for their single enemy to pass between them. Without doubt future engagements will be fought at long range. While engaged on one side only, the battery of type 5 is able to deliver in one minute an energy of fire represented by 253,170 foot-tons, against 230,620 foot-tons for type 4. It is true that the latter type is able to deliver at the same time the same energy of fire on the opposite side, and type 5 can deliver on both sides at the same time but 220,530 foot-tons, which is a little less than

in the case of type 4. The former type has, however, a great advantage over the latter in the fact that it delivers its maximum fire over 100 degrees of arc, while the latter delivers it over only 64 degrees. It will thus be seen that type 5, will still have the advantage, even while engaged on both sides.

11. The firing diagrams for types Nos. 4 and 5, as stated in paragraph 10, are calculated for one minute, and based on the following data:

The 8-inch gun will be fired at the rate of 1.2 rounds per minute.

The 7-inch gun will be fired at the rate of 2.5 rounds per minute.

The 6-inch gun will be fired at the rate of 3.5 rounds per minute.

Eight-inch gun, muzzle energy per minute, 16,322 foot-tons.

Seven-inch gun, muzzle energy per minute, 23,062 foot-tons.

Six-inch gun, muzzle energy per minute, 20,433 foot-tons.

Eight-inch gun, weight of metal thrown in one minute, 300 pounds.

Seven-inch gun, weight of metal thrown in one minute, 412.5 pounds.

Six-inch gun, weight of metal thrown in one minute, 350 pounds.

These data were supplied to the members of the Board by the Chief of the Bureau of Ordnance. Any decrease in the rate of fire of the 7-inch guns, or any increase in the rate of fire of 8-inch guns, will favor type 5. It is understood that the rate of fire given for the 8-inch and for the 6-inch gun is the result of actual practice on board ship. The fire of the 7-inch gun, however, is assumed by the Chief of Bureau of Ordnance, for the reason that no 7-inch gun exists.

I believe that the 7-inch gun in this table is highly favored, for the following reasons:

Roughly speaking, the ratio between the 7-inch and the 6-inch guns is as two to three, while the ratio of the 7-inch to the 8-inch is two to one. In other words, the 7-inch gun can fire two shots while the 6-inch is firing three and the 8-inch one.

The 6-inch shell, weighing 100 pounds, is the largest that can be handled by one man. Two men with tongs are required to handle the 7-inch shell, weighing 175 pounds, and two men with tongs can also handle an 8-inch shell, weighing 250 pounds. It is believed, therefore, that the time required for loading the two guns, 7-inch and 8-inch, will be very nearly the same. It is supposed that a 7-inch gun on a pivot mount presents certain advantages over an 8-inch gun mounted in a turret. This, however, requires demonstration, since we are as yet without experience in the matter. The rate of fire given for the 8-inch gun has been obtained in the slow-moving, steam-manipulated 8-inch turrets, and it is expected that it will be considerably increased in turrets manipulated by electricity, where each gun has a separate ammunition hoist in place of one for two, as at present.

A conservative statement of the rate of fire of 8-inch quick-firing guns abroad is one shot every twenty seconds, or four shots the first minute and three for every minute following. There is a record abroad of four 8-inch aimed shots having been fired by an untrained crew in sixty-two seconds (O. N. I.). There is also a record of six unaimed shots per minute having been fired at the experimental battery from an 8-inch gun with a specially-designed breech mechanism.

I confidently believe, for the above reasons, that the pink firing diagrams should be more in favor of type 5 than represented.

12. *Tactical Advantages.*—Attention is invited to the greatly superior tactical advantages of type 5. This is well represented by the area of pink coloring in the firing diagrams. As clearly shown, this type of ship can be fought advantageously in any formation.

Type 4 presents a ship suitable only for a broadside engagement and for a column formation.

13. *Homogeneity of the Fleet.*—The homogeneity of the fleet is a most important element. Type 4 corresponds only with the *Alabama* and *Maine* classes. I do not hesitate to assert that these ships possess a weak battery, and the omission of 8-inch guns from their armament is much regretted by the best-informed officers of the Navy. While there are six of the

above-mentioned classes armed only with 12 and 6-inch guns, the latter in broadside, there are eleven ships built and building having 8-inch guns mounted in turrets.

The English have adhered for a long time to the 12 and 6-inch guns, the former in turrets and the latter in broadside, but recently have adopted larger calibers, and their two latest types of battleships are armed as follows:

Queen class:

Displacement,	15,000 tons.
Speed,	19 knots.
Armament,	4 12-inch guns. 8 7.5-inch guns. 10 6-inch guns.

Nelson class:

Displacement,	18,000 tons.
Speed,	20 knots.
Armament,	4 12-inch guns. 4 9.2-inch guns. 10 6-inch guns.

The latest type of German battleship laid down is said to be designed for the following armament:

Four 11-inch guns mounted in pairs.

The balance of the battery to consist of either 5.9-inch or 8.2-inch quick-firing guns.

That the latter should be even considered is a new departure for Germany, she having kept her guns at lower caliber than most countries.

The most recent type of French battleship laid down is as follows:

Displacement,	14,965 tons.
Armament,	4 12-inch guns in pairs in turrets. 18 6.4-inch quick-firing guns, 12 in pairs in turrets and 6 in casemates.

The latest type of Italian battleship laid down is as follows:

Displacement,	. . . . .	12,625 tons.
Armament,	.	2 12-inch guns in barbettes. 12 8-inch quick-firing guns in pairs in turrets.

To the unprofessional mind it might, perhaps, appear to be a good plan to build varying types of ships in order to make sure that some one type shall be the best. This would be a great error, since nothing is worse than a patchwork fleet, some of one kind and others of another. The wisdom of adopting the 8-inch gun as a part of the battery of our battleships has been clearly demonstrated and is being rapidly followed by foreign nations. No reduction in caliber should be entertained.

The 7-inch Gun.—14. At present the Navy is without a 7-inch gun. A gun of this caliber and its mount are under construction for experimental purposes. All statements concerning its character are either assumed or the result of theoretical considerations. It does not seem to me wise to adopt for our battleships guns of an untried type. Not only the gun should be fully tested, but a suitable mount should be designed, constructed, and also tested.

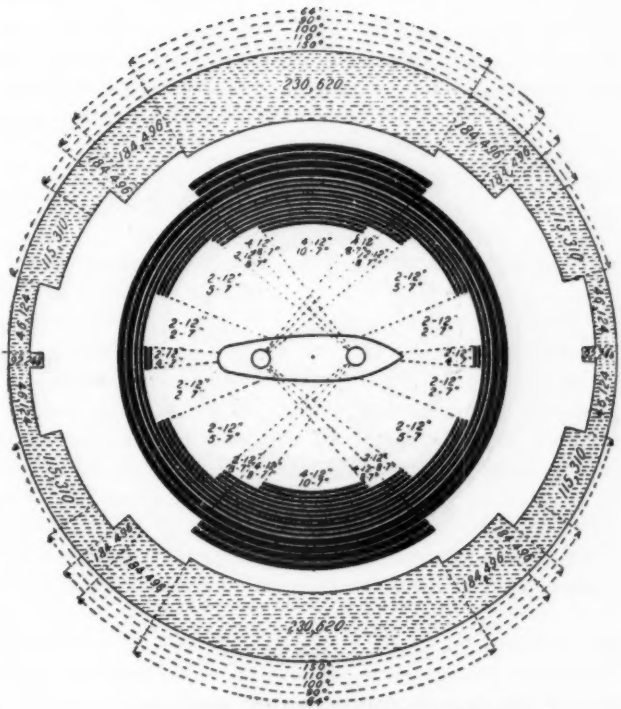
I am also of the opinion that even should the 7-inch gun fulfill the expectation of the Bureau of Ordnance it cannot replace both the 8-inch and the 6-inch guns. Its shell will lack the penetration and destructive effect of the 8-inch shell, and it will fail to produce the smothering effect of the very rapid fire of the 6-inch gun.

In this connection, the following quotation taken from the prize essay of the Royal United Institution for 1900 is pertinent:

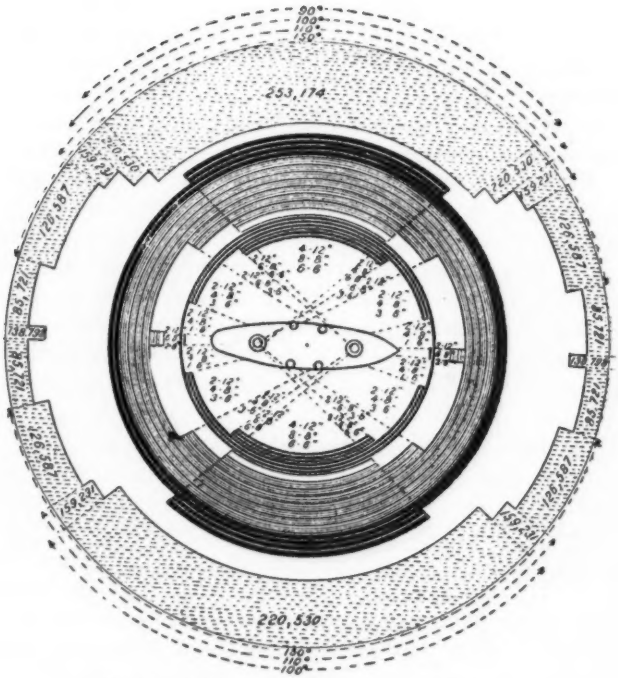
"It is here considered that, strictly speaking, no gun of more than 6-inch approximate caliber can rightly be called a quick fire."

A little more than one year ago, when the armament of the *Virginia* class was being considered, the Chief of Ordnance was opposed to the use of the 7-inch gun in battleships, as shown by the following memorandum addressed to me:

"I think, on the whole, that for the battleship the 8-inch gun



No. 4.—RECOMMENDED BY MAJORITY.



No. 5.—RECOMMENDED BY MINORITY.

is preferable to the 7-inch. The latter will be a more suitable weapon for the superstructure guns of the armored cruisers. I shall, therefore, favor the scheme of having four 8-inch turrets, two on each beam, and, in order to improve the armor protection, propose that the total coal be made 1,800 tons instead of 2,000, and that 800 tons be carried on trial instead of 1,000, thus saving 200 tons on trial displacement. This 200 tons will be sufficient to add 2 inches to the heavy part of the main belt, which is 181 feet long, making it 11 inches, tapering to 8 inches, instead of 9 inches, tapering to 6 inches, as at present.

(Signed) "CHARLES O'NEIL,
"*Chief of Bureau of Ordnance.*

"REAR ADMIRAL BRADFORD."

If it was unwise to assign 7-inch guns to battleships one year ago it is unwise to do so now.

Superposed Turrets.—15. The opinion of the Chief of the Bureau of Ordnance is entitled to great weight in connection with the selection of a battery for a battleship, and also as to the best method of mounting and protecting the same. Attention is invited to the fact, however, that the present Chief of Ordnance concurred in the armament adopted for the five battleships of the *Virginia* class under construction.

Attention is also invited to the fact that his predecessors for about sixteen years, viz: Admiral Sicard, Admiral Sampson and Captain Folger, have all in the past advocated the superposed turret.

. The result of gun fire and target practice on board of the *Kearsarge* and *Kentucky* is in favor of the superposed turret, and, so far as I am able to ascertain by diligent inquiry, the officers of both ships, without exception, are heartily in favor of this type of turret.

The majority of the Board on Construction favoring type 4 is made up of the Chief of Ordnance, the Engineer-in-Chief and the Chief Constructor. Previous to this date the Engineer-in-Chief has been a warm advocate of the superposed turret. While he voted for type 1, when considered by the Board on Construction

something over a year ago, he subsequently explained, when a member of the large Board of thirteen, that this was an inadvertence, and then voted for the superposed turret type.

At various times during the past year and a half no less than five of the senior naval constructors of the service have been members of the Board on Construction. Notwithstanding the many advocates of the superposed turret among the line officers, the above-mentioned constructors have opposed it at all times.

In fact, so far as known, out of a corps of forty naval constructors there is not a single advocate of the superposed turret. It is submitted that this in itself is sufficient to suggest either a corps policy or prejudice against this form of turret.

The unfavorable criticisms of the superposed turret are thus far purely theoretical. In practice they have fulfilled every expectation of their advocates.

16. *Gun Protection.*—As already stated, type 4 has but two turrets, casemate armor and splinter bulkheads being relied upon for the protection of the twenty 7-inch guns. This is directly at variance with the present system abroad, particularly in the navies of France, Russia, Germany and Italy, where great efforts are made to isolate all guns by placing them either in turrets or casemates, singly or in pairs, on account of the great danger of destruction or damage by shells penetrating casemate armor. A sketch is forwarded herewith showing some of the latest types of battleships of this pattern.

Your attention is invited to the crowded condition of the guns on the main deck of type 4, and the probable effect of a 12-inch melinite or lyddite shell exploding anywhere in the vicinity of the guns. Such an explosion may be expected, since the target is large and the armor easily penetrated at long ranges by shells of 8-inch caliber or above.

The first sketch plan of a battery of 7-inch guns was prepared by the Chief of Ordnance. He placed twelve 7-inch guns on the main deck, with six on a side, and eight on the deck above, with four on a side. This was changed by the Chief Constructor as indicated in the diagram. In my opinion the change was

unwise on account of the crowded condition of men and guns on the main deck.

The following extract from a report on "The Protection of Gun Positions," wherein a comparison is made between certain foreign and our own battleships of the *Kentucky* class, by one of the best informed officers of the Navy, is quoted, as presenting important data on this subject:

"That the extreme probability of the *Kentucky's* 5-inch battery and gun crews being quickly destroyed, when exposed as above indicated, has not been exaggerated appears to me practically demonstrated by the following details of the appalling effects produced on the gun deck of the central battery, coast-defence ship *Belleisle* by a few minutes fire from the *Majestic's* battery. These details, many of which I have not previously seen reported, have lately been given to me. * * *

"The four large guns and 6-pounders in the *Belleisle's* battery are installed on an open gun deck; that is, none of the guns are in enclosed compartments. The officers estimated the area of each gun port to be 28 square feet and the three 6-pounder ports 20 feet, or in all 76 feet in each broadside, or three-fourths of the total area of the *Kentucky's* ports on one side. The entire area of the large ports was not exposed when the *Majestic* was abeam, or nearly so, as the area of each includes a part of the port in the end of the superstructure.

"There were fired in all about 1,400 shots from all calibers, of which about 1,200 were 12 and 6-pounders. The following are the expressions used by the officers in describing the effects of the firing.

"'The gun deck was a frightful wreck. You could not have believed such havoc could have been made in such a short time. It is hardly possible to give you much of an idea of the amazing effect of some of the shell.

"'Of the 83 wooden manikins that had been secured in their positions at the guns there did not remain a piece of any one of them as large as your hand. We do not believe they were cut to pieces solely by fragments of shell, for they were mostly in splinters, as though whole crews of them had been shattered by

the blast of an exploding shell, doubtless lyddite. The conning tower was struck several times, but not pierced, and we were consequently very much surprised to find the four manikins that had been stationed therein almost as badly shattered as those on the gun deck.

"'Two of the large and all of the 6-pounder guns were totally disabled. Two of the 6-pounders were completely destroyed, the guns themselves being bent and twisted in the most inconceivable manner. One of them was found on the spar deck, having been blown up through the deck by a shell exploding under the mount.

"'The decks were breached in many places and almost the entire planking was ripped away from its fastenings.

"'A lyddite shell exploding in the cabin shattered the bulkheads and almost completely pulverized a massive marble tub in the bath room. The largest piece we could find was no bigger than the end of your little finger.

"'A shell exploding under the seamen's head ripped it from its fastenings and landed it, upside down, 20 feet abaft of its original position.

"'Rifles and cutlasses that had been in their racks (for nothing was removed from the ship) were found scattered all over the deck and twisted into the most peculiar shapes. Some that showed no marks of having been struck by any fragments were rolled up spirally like a watch spring.

"'Solid shot seemed to have done comparatively little damage. One 6-inch armor-piercing shell made a clean hole in the 9-inch armor and brought up against the breech of a heavy gun, beneath which it was found.

"'The beams, decks, bulkheads, etc., were so completely scored and cut by flying fragments that it seemed as though the superstructure must have been filled with them. The decks were strewn with a great quantity of metal splinters of every conceivable shape. The marks of small rapid-fire shell were literally everywhere.

"'The fire mains were cut in many places and the lower decks had 3 inches of water on them when we came on board. The first thing we did was to stop the pumps, which had been started

when the vessel was abandoned with full steam on the boilers. We believe the drenching of the decks from the mains prevented the ship being set on fire.

"'In two minutes after the firing commenced the *Belleisle* was almost entirely obscured by the smoke of the shell exploding on her. There was so much of it that the journalists (who were kept at a distance) reported that she had been set on fire and was burning up. About 20 per cent. of the shell used were lyddite, and all the others had black powder charges. We were much disappointed at not finding any traces of the explosion of the 12-inch shell on the gun deck, as we wanted particularly to know their effect. The 6-inch and rapid-fire shell seemed to have done the business, especially the latter.'" * * *

Displacement.—16. I concur with the majority of the Board as to the general type of ship recommended, so far as displacement, speed, coal endurance, etc., are concerned.

I understand that the dimensions of both type 4 and type 5 are given in the majority report. It is only necessary to add here that type 5, recommended by me, requires about 300 tons greater displacement than type 4.

It is proper to add that with this addition the displacement will be 15,860 tons, while the English are laying down battleships of 18,000 tons displacement.

Policy.—17. The armament of the ships of the *Virginia* class was assigned only after the most careful consideration and discussion by many of the ablest officers of the Navy. I consider it very unfortunate that the majority of the Board on Construction should now recommend an armament for additional battleships so different in caliber and so differently disposed, protected and mounted. The natural effect will be a loss of confidence in the knowledge of the Board as to the type of battleship best suited for naval purposes.

I therefore recommend the most careful consideration of the subject by the best authorities the Department is able to command.

Very respectfully,

R. B. BRADFORD,
Chief of Bureau of Equipment, Member.

SUPPLEMENTARY REPORT OF THE MAJORITY.

NAVY DEPARTMENT, BOARD ON CONSTRUCTION,
WASHINGTON, *July 24, 1901.*

1. In reviewing the report of the minority the majority take exception to such parts thereof as call in question the motives or the judgment of any member of the Board, being of the opinion that the discussion should have been confined strictly to the merits or defects of the respective plans submitted, and that any other line of argument is inadmissible.

2. Inasmuch, however, as each party has been accorded the privilege of reviewing the report of the other, the majority take occasion to comment as follows with regard to certain passages in the minority report:

"*Absence of turret protection and the reduction in caliber are marked features of No. 4 design, to which officers generally have heretofore shown a marked disapproval.*"

3. The above statement, contained in the minority report, is at variance, so far as turrets are concerned, with the information received by the majority. While it is a fact that a certain number of officers—perhaps seven or eight—serving on technical boards expressed themselves as favorable to 8-inch guns in turrets, it was chiefly due to the fact that they were convinced that guns of so large a caliber could not be advantageously mounted otherwise, but the general tenor of reports received during the Spanish-American war was not favorable to guns in turrets.

"*I believe that the 7-inch gun in this table is highly favored,*" *etc.*

4. In reply to the above the majority would state that such is not the case. The very moderate rate of fire, viz: 2.5 rounds per minute, accorded to this caliber by the Chief of the Bureau of Ordnance, is believed to fairly represent its efficiency in action. On the proving ground there is no doubt whatever that a record of from five to seven rounds per minute can and will be obtained from this gun, and guns with quick working mechanism, mounted singly on pedestals, can be served more rapidly than can guns in turrets; there is more space about them and fewer mechanical details to operate. The rate assigned to 8-inch guns in turrets, namely, one round in fifty seconds, is believed to fairly represent

what may be expected in action. The reference made by the majority to an experimental 8-inch gun which fired six unaimed shots per minute (that is, for one minute only, beginning with the gun loaded) did not represent service conditions, and after a few rounds it required the united efforts of half a dozen men on a rope attached to the operating lever to open the breech, and the mechanism was so faulty that it was discarded.

"*At present the Navy is without a 7-inch gun.*"

"*It does not seem to me wise to adopt for our battleships guns of an untried type.*"

5. With reference to the above quotation from the minority report, the majority desire to state that such a line of argument might with equal propriety be applied to the proposed vessels themselves. There is no question whatever as to the ballistic and other properties of a 7-inch gun. It can be calculated with as great a degree of accuracy as could the 3, 4, 5, 6 and 12-inch new guns, all of which have fulfilled in the highest degree the requirements designated for them; and the 7-inch gun, one of which is now about ready for the proving ground, will, without any doubt, fulfill all that is expected of it.

6. It may be remarked that the new type of 8-inch gun, which is to form part of the battery of five battleships and six armored cruisers, now building, and which the minority proposes for its plan, has never yet been tried, the type gun not being yet completed. Hence, if there is any doubt as to the efficiency of the new 7-inch gun, there is an equal doubt as to the new 8-inch. In point of fact, however, there is no doubt in either case.

7. The Chief of the Bureau of Ordnance comments as follows regarding his memorandum to Rear Admiral Bradford concerning the use of 7-inch guns, which is embodied in the minority report:

"While this memorandum is correctly quoted, any consideration of it without reference to the matter it referred to would be misleading. The question then under consideration was a combination of 6 and 7-inch guns for the intermediate battery of battleships then under consideration, the propriety of using 7-inch guns in the superstructure having been discussed. No proposi-

tion was then entertained of a homogeneous battery of 7-inch guns, as is now proposed by the majority, it being a case of two calibers—6-inch and 7-inch, 6-inch and 8-inch, or 7-inch and 8-inch—which finally brought forth the memorandum referred to.

"Reference is made to the fact by the minority that certain predecessors in office to the present Chief of the Bureau of Ordnance advocated the use of superposed turrets, to which the Chief of the Bureau of Ordnance replies that such a line of argument is inadmissible, as it is calculated to discredit the judgment of the present Chief of the Bureau of Ordnance because he does not agree in all things with his predecessors.

"The minority calls attention to the fact that the present Chief of the Bureau of Ordnance concurred in the armament adopted for the five battleships of the *Virginia* class, to which he replies that such is the case, but that he did not do so from conviction that it was the best scheme (having submitted a battery plan which he considered preferable), but because he was in the minority of a board ordered to consider the case, and being outvoted was willing to sign with the majority, upon the principle that the sentiment of the majority should be the report of the board. He desires to state, however, that he is not an advocate of superposed turrets, regarding them as unmilitary and unmechanical structures, having no justification for their existence except for two causes, namely, saving of weight and space. The enforced concentration of four guns, differing by pairs from each other in energy, rate of fire, etc., does not offer any tactical advantage, but results in tactical disadvantage, dispersion of fire, with the possibility of concentration when desired, being preferable to enforced concentration.

"*The unfavorable criticisms of the superposed turret are thus far purely theoretical.*"

8. In answer to the above statement in the minority report, it may be remarked that the advantages claimed for them are also purely theoretical.

9. The majority desire to lay great stress on the fact that with the vessels now building there will be, when they are completed, seven battleships having superposed turrets, which, to the ma-

jority, seems as great a number as is warranted in default of any but theoretical reasons therefor.

10. With reference to the remarks contained in the minority report relating to the alleged opposition of the corps of naval constructors to superposed turrets, the Chief Constructor comments as follows, the majority concurring therewith:

"In designing ships, and with special reference to the arrangement of the battery, the greatest importance is naturally given to securing the greatest possible arc of fire for each gun. The results obtained in this respect by the use of the superposed turret give to any battery plan an advantage which is more imaginary than real, because it is considered that each gun in the four-gun turret is of equal efficiency to a gun mounted singly. For instance, in all diagrams of weight of fire it is presumed that these four guns are as efficient as if each could be trained independently; whereas, each being secured to its turret, and the turrets immovably fixed together, they must train together in a horizontal plane.

"In the following remarks it is intended to be shown that the four-gun turret as a weapon of offense is objectionable, owing to the greatly reduced efficiency per gun, due to the interference of one gun with another in actual operation, and that the four-gun turret is also seriously objectionable from the increased target exposed and the liability to having a larger proportion of the battery placed out of action by a single well-placed shot of small caliber.

"The efficiency of a gun is measured by the number of hits which can be made in a definite time.

"The maximum efficiency of any gun is necessarily obtained when mounted singly, and considering that the guns in this comparison each have the same arc of train, the efficiency of a gun mounted singly will be called 100.

"This has been thoroughly recognized by the French in all their designs and they have only recently yielded to mounting guns in pairs, in spite of the obvious weight saving thereby effected.

"For purposes of economy in weight of armor, turret sup-

ports, gun mountings, ammunition hoists, or for economy of room and other reasons guns are mounted in pairs. This necessarily decreases the efficiency per gun, because the guns must train together and the firing of one gun necessarily interferes with the firing of the other. The reduced efficiency per gun of guns mounted in pairs must be less than 100 and may be considered, for the purposes of argument, as 75.

"When *four* guns are mounted in one turret, which is the practical result of the double turret now in use, the efficiency per gun is further reduced; and supposing for the moment that the four guns are of the same caliber, the efficiency per gun must be less than 75 and a fair assignment would be, say, 50. Therefore the total gun efficiency of the double turret would be 200, or equivalent to two guns mounted singly.

"It is naturally difficult to obtain the same arc of train for the four guns considered as mounted independently, and, therefore, some allowance is necessary from the proportions above given. On the other hand, some increase of these proportions is due to the fact that the four guns in the turret are not of equal caliber and that guns of small caliber are very considerably reducing the efficiency of guns of larger caliber.

"A plain comparison of the gun mounted singly and the four-gun turret is of the results which would be obtained by one sportsman shooting birds with a four-barrel gun and four men shooting with single-barrel guns.

"All the preceding considerations relate to the subject from the point of view of *offense*, but when the subject is considered from the point of view of *defense* the four-gun turret provides a very considerable economy of weight and space, but exposes more than one-third of the total battery of the ship to disablement, either from one shot of the enemy or from slight derangement of the mechanical devices it contains.

"There can be no question that the placing of the 8-inch turret on top of the 13-inch turret considerably increases the danger of disablement of the 13-inch turret and also of the 8-inch turret itself. This is very conclusively shown in the following extract from a report on the protection of gun positions, wherein a com-

parison is made between certain foreign and our own battleships of the *Kentucky* class, by a well-informed officer of the Navy. In regard to the chances of total disablement from either an internal accident or a small shell entering the port opening, he says:

"' * * * A baseball tossed into one of the ports would fall directly into the 13-inch handling room, opening into which are the 13-inch, and below which are some of the 8-inch magazines. In action, at least four charges would be exposed either in the ammunition hoists or ready to be put into them. There can therefore be no reasonable doubt that the explosion of a large or even medium caliber shell in the 13-inch turret would not only inevitably destroy the guns' crews and put the entire system out of action, but would, in all probability, explode the 13-inch and 8-inch magazines, as well as the 5-inch main magazines that are immediately adjacent to them, thus entailing the complete destruction of the vessel.'

"With reference to the additional danger of disablement of each turret, due to the fact of their superposition, he says:

"' * * * I have appended a sketch showing a projection of the end-on view of the superimposed turrets against a British "record practice" target; and on the latter I have plotted the actual record made by H. M. S. *Terrible* in 1900. * * * The target therefore represents the fire of the guns on one side; that is, six 6-inch guns during four minutes. * * * The *Terrible's* record showed 104 shots and 80 hits with the 6-inch guns on the regular target (16 by 20 feet). Seventy-nine of the 80 hits would have struck one or the other of the *Kentucky's* turrets. * * * Twenty-six and six-tenths per cent. are on the 8-inch turret. As these shots would have passed over a single turret and been wasted, it is clear that the 8-inch turret, in this position, acts as a "save all" for line shots going too high, and that consequently its chances of being hit are much greater than if it stood by itself. * * * Projecting the *Canopus* turret or shield against the target, it will be seen that it would have received 36 of the 79 shots, or 45.5 per cent., thus illustrating the relative value of the low target.'

"The experience gained with the double turrets on the *Kearsarge* and *Kentucky* has been sufficient to show that the features of the design, so far as they relate to the mechanical means of operation, are successful; but the features of the design, so far as they relate to the efficiency of the superposed turret as a weapon of offense, have not been developed by any practical tests. The guns have been fired at target practice in various ways, some defects in the gun mountings have been developed and remedied, but no serious test of the four-gun turret, to compare its efficiency with the two-gun or one-gun turret, has ever been made.

"It is clear, from the line of argument adopted in the beginning of this statement, that it is perfectly practicable to make a test of the turrets of the *Kearsarge* and *Kentucky*, which would determine the efficiency per gun from actual trial.

"The general outline of the tests would be as follows:

"A large target should be used, say 60 feet long at the bottom, 20 feet high, and 30 feet long at the top. This target should be anchored and moored with its length parallel to the course which the ship shall take. The firing should take place at ranges varying from about 2,500 to 1,500 yards, with the vessel moving from 6 to 8 knots per hour, and extend over a length of time of not less than twenty minutes.

"The *Kearsarge* should make the following runs over the course:

"(1) Firing the starboard 13-inch gun of the forward turret.

"(2) Firing both 13-inch guns of the forward turret.

"(3) Firing all four guns of the forward turret.

"The *Alabama* should make the following runs:

"(1) Firing one 13-inch gun of the forward turret.

"(2) Firing both 13-inch guns of the forward turret.

"The *Brooklyn* should make runs similar to those of the *Alabama*, firing the 8-inch guns of the forward turret."

NOTE.—Actual hits only to count.

These tests certainly should be made, and the results would be required to show a very high order of efficiency in powers of

offense to justify the adoption of a device which has such transparent defects in defense.

Respectfully,

CHARLES O'NEIL,
Chief of Bureau of Ordnance, President of Board.
GEO. W. MELVILLE,
Engineer-in-Chief, U. S. N.,
Chief of Bureau of Steam Engineering, Member.
F. T. BOWLES,
Chief Constructor, U. S. N.,
Chief of Bureau of Construction and Repair, Member.

THE SECRETARY OF THE NAVY.

SUPPLEMENTARY MINORITY STATEMENT COMMENTING UPON THE MAJORITY REPORT ON THE PROPOSED NEW BATTLESHIPS.

NAVY DEPARTMENT, BUREAU OF EQUIPMENT,
WASHINGTON, D. C., *July 25, 1901.*

The majority report is referred to by paragraphs.

Paragraph 6.—It is stated by the majority that the most "efficient method" of obtaining the extra 300 tons displacement required for the design recommended by the minority is to add 5 inches to the draught of water. The report then goes on to state that this increased draught is objectionable. I concur with the majority that this increased draught is objectionable, but I do not concur in its necessity.

Paragraph 7.—It is stated that the majority design "simplifies the construction of the ship and the mounting of the battery by reducing the number of turrets from eight to two," etc. In the design offered by the minority I did not consider the question of simplicity of construction, but efficiency as a fighting machine, which I submit is the most important factor.

Paragraph 9.—The majority claims in its design the following superiority, viz: "To mount the auxiliary guns singly in broadside, gaining marked advantages as regards rapidity of fire and simplicity and ease of ammunition supply, and avoiding the numerous practical objections to the mounting of guns in turrets, which are generally recognized, and were particularly brought

to the attention of our officers who saw active service during the Spanish-American war." On this statement I submit the following comments, viz :

The "increased rapidity of fire" is purely theoretical. The rate of fire given for the 7-inch guns by the majority is an assumed rate and not based on experience. As stated in my report, the difference in rates of fire between the 7 and 8-inch guns, given by the majority, is, in my opinion, too great and not warranted by the actual rapidity of fire obtained at home and abroad with the *latest* types of 8-inch guns.

In order to supply ammunition directly and efficiently it will require as many magazines and shell rooms for the twenty 7-inch guns as for the twelve 8-inch and twelve 6-inch guns. The rapidity of fire claimed for the 7-inch gun cannot be maintained without an ammunition hoist for each gun, and a large number of magazines and shell rooms in close proximity to the ammunition hoists. The same statement applies to the battery proposed by the minority, with this exception, viz: For 8-inch turret guns the magazines, shell rooms and ammunition hoists are more compactly arranged and constitute in themselves a distinct unit, ensuring a direct and rapid supply of ammunition.

The numerous practical objections to mounting guns in turrets, referred to by the majority as recognized and brought to the attention of officers actually engaged in the late war, are not stated and are unknown. I believe, however, after inquiry, that the sentiments of officers who served in turret ships in Cuban waters during the Spanish-American war are very much in favor of the use of 8-inch guns mounted in turrets. Objections have been made in the past to certain types of mounts supplied for 8-inch guns and to certain methods of revolving the turrets; no objection, so far as known, has ever been made to a mount reasonably efficient, or to a turret trained with the aid of electrical power.

Paragraph 11.—In this paragraph the majority admits that the isolation of guns, claimed by the minority as a great advantage, is correct in principle. This is followed by a statement, however, that the protection afforded by the design of the majority is equal to that of the minority, because by the use of a superposed turret

in the minority design four guns in two instances may be disabled by a single shot. In order to accomplish this it will be necessary to penetrate the lower turret. This cannot be accomplished except by the largest shell striking normally. Attention is invited to the extreme improbability of such an event.

This objection to superposed turrets is the only one remaining of all the numerous objections originally so strenuously urged against it. The positive value of this objection can not be determined except by actual experiments, both costly and difficult to make.

If the 8-inch turrets are made the same thickness as casemate armor, the additional protection afforded by their shape is self-evident.

On this subject of protection I invite especial attention to the fact that sixteen of the guns of the minority design, which constitute by far the most important portion of the battery, are located in widely-separated positions, surrounded by armor disposed in the best manner to protect the guns and their crews; also, that two of these gun installations, each with an aggregate of four guns, afford a very great arc of fire and a disposition of armor which make them almost proof against destruction. Further, that the remaining twelve 6-inch guns can be mounted and protected as advantageously in every way as the 7-inch guns proposed by the majority.

I claim that when fighting in broadside the isolated gun positions afforded by the minority design have a manifest advantage over the concentrated battery of the majority design, with reference to damage to guns and personnel from an enemy's fire. If fighting ahead and astern, or on the bow or quarter, an enemy's shells penetrating the casemate armor of the majority design must cause great destruction to the guns and men massed on the main deck, while the greater part of the battery would be unable to reply, always a source of demorilization to the crew.

In this connection, attention is invited to the great volume of fire from the entire arc of 360 degrees afforded by the minority design.

Paragraph 13.—I did not discuss, when presenting the minority

design, the secondary battery. I did not suppose, nor do I now, that type 5 could not carry, without any additional displacement, as large a secondary battery as type 4. Since both reports were made it has been admitted by the majority that the secondary battery of the minority design can be largely increased without any additional displacement.

Paragraph 14.—The majority in its report classifies the 7-inch gun as a rapid-fire gun. Attention is invited to the statements of the minority report, paragraph 14, concerning this gun.

Paragraphs 15 and 16.—The majority in these two paragraphs makes a comparison between the new 7-inch gun as *designed* and an old and obsolete type of 8-inch gun. It is submitted that this is not relevant. The new type of 8-inch gun is to be used in the *Virginia* class of battleship, and it goes without saying will be used in all future constructions. All comparisons between the 7-inch and 8-inch guns, to be fair, should be for types with the same muzzle velocity. The "Table of Elements" for a 45-caliber 8-inch gun (model of 1899), published by the Bureau of Ordnance, provided for a gun of 18 tons weight, with a muzzle energy of 13,602 foot-tons. The theoretical weight and muzzle energy of the 7-inch gun is 13.3 tons and 9,225 foot-tons. These figures present a fair comparison of the weight and power of the two guns. It should be borne in mind that all guns, the world over, are being improved, and that their relative power remains about the same.

In regard to the ease of manipulation of the 7-inch gun, there is no data to base any statements upon, while the 8-inch gun, mounted in turret, can be manipulated with great ease and rapidity by means of electrical power.

Paragraphs 17–23, inclusive.—The majority cite certain examples of the use of the 8-inch guns in action, for the purpose of proving that this gun, mounted in turret, is slow and inefficient. It is noted that only the number of shots fired by different ships is considered. To make the comparison of value the time of each ship under fire should be stated. It is admitted that any gun mounted in the open is more efficient in its fire than one mounted in a turret. It is here that the question of what is ab-

solutely necessary in the way of protection should be considered. The accuracy of the enemy's gunners is also a factor that must not be neglected. A study of the recent *Belleisle* experiments while subjected to a few minutes fire from the British ship *Majestic* is pertinent. The selection of the *Olympia's* turrets for a comparison was unfortunate, since her 8-inch gun mounts, sights and training mechanism, are all obsolete and have been for some years past. They are now being changed at the Boston Navy Yard.

The question at issue has nothing whatever to do with the old type of 8-inch gun and its appliances, including mounts, sights, turrets, etc. What the minority does claim is that the latest type of 8-inch gun, with its improved mounts, sights, turrets, turret-moving mechanism, etc., should be used in the new battleships in preference to a newly designed and untried 7-inch gun of much less power. Uniformity of caliber is now of much less importance than formerly, when ammunition for different calibers was all stowed in the same magazines and shell rooms. At present, shell rooms are constructed for each caliber of guns, with separate hoists and other appliances.

Paragraph 25.—In reference to the statement in this paragraph, the minority desires to emphasize the importance of the heavy *all-around* fire provided for in the design presented. It was not intended by the minority to neglect or overrate the importance of either broadside or end-on fire; both are good in its design. Whether future naval engagements will chiefly be fought on the broadside or not, ships must approach and separate end-on, or nearly end on.

R. B. BRADFORD,
Chief of Bureau of Equipment, Member.

Adder, Fulton, Moccasin.—These three submarine boats building by Mr. Lewis Nixon, Elizabeth, New Jersey, have been launched: The *Adder*, July 22d; the *Fulton*, June 12th, and the *Moccasin*, August 20th. They were described on page 475 of the current volume.

Bailey.—The following are the principal details of this torpedo

boat, a notice of whose trial was given on page 472 of the last number of the JOURNAL.

Length between perpendiculars, feet	205
Breadth, extreme, feet	19.23
at water line, feet	18.76
Displacement, normal, tons	245.7
Bunker capacity, tons	98.5
Feed-tank capacity, gallons	2,064
Reserve feed-tank capacity, gallons	700

The engines are of the twin-screw triple-expansion type, with cylinders, 20, 30½ and 32 inches diameter, there being two of the latter; the stroke is 18 inches. The piston rods are 3¾ inches in diameter.

There are four boilers of the Seabury type, having a single steam and a single water drum, with tubes following the general contour of the vessel connecting them. The boilers are 12 feet long, 10 feet 6 inches wide and 12 feet high, and have a furnace 6 feet 3 inches wide and 9 feet long. The total grate and heating surfaces are respectively 225 and 13,200 square feet.

There are four single-acting combined air and feed pumps, each operated by a compound engine having cylinders 5 and 10 inches diameter by 6 inches stroke. The air pumps have buckets 12 inches diameter and 6 inches stroke, and the feed pumps plungers 3½ inches diameter and 6 inches stroke. In addition, there are four auxiliary feed pumps of the Blake type.

Other data are:

Condensing surface, both condensers, square feet	3,936
Circulating pump, diameter of runner, inches	20
engine cylinder, inches	5
stroke, inches	3
Blowers (4), diameter of fan, inches	60
engine cylinder (1), inches	4¾
stroke, inches	8
induction nozzle, square inches	998
eduction nozzle, square inches	1,885
Screw propellers, diameter, feet and inches	6–10
pitch, mean, feet and inches	9– 1½
developed area each, square feet	16.42
Weight of machinery and water, tons	144.456

The trials for the standardization of her screws were run in December and January of last year, but the official trial was delayed on account of the cold weather. The results of the standardizing trials were:

Steam pressure.	Air pressure.	Revolutions per minute.	Speed.
102	n. d.	244.5	20.8
120	n. d.	281.25	23.165
141	2.25	300.75	24.28
191	4.75	385.5	29.05
...	...	391.8	29.39
...	...	377	28.8

After drawing a fair curve through the points determined from these trials, it was decided that it would be necessary for the engines to make 403 revolutions per minute in order to reach the contract speed of thirty knots.

The official trial was run on the 25th of April, the vessel having a mean draught of 7 feet at the beginning, corresponding to 295 tons displacement, and a mean draught of 6 feet 8 inches at the end, corresponding to 265 tons displacement. The mean displacement for the trial was, therefore, 280 tons. There was moderate wind, with occasional squalls during the trial.

The mean results for the two hours were:

Steam pressure, boilers, pounds	217
first receiver, pounds	75
second receiver, pounds	18.65
Vacuum, inches	21.6 and 15.5
Revolutions per minute, main engines	405.66
air pump	370
feed pump	160
blowers	700
dynamo	700

Bainbridge.—One of the three torpedo-boat destroyers, building by the Neafie and Levy Ship and Engine Building Company, of Philadelphia, was successfully launched from their yard on Tuesday, August 27th. All of her machinery is on board, and it is expected that she will soon have a builders' trial.

Goldsborough.—On the 12th of June another attempt was

made to run the official trial of this torpedo boat, but after running for one hour and twenty-five minutes the low-pressure rock-shaft arm of the starboard engine broke. She is being prepared for another trial at the Puget Sound Naval Station. For the period of this trial the average revolutions of her engines were 294, and the maximum for a 15-minute period 322.

Maine.—The battleship *Maine* was launched by the William Cramp and Sons' Ship and Engine Building Company on Saturday, July 27th.

Stringham.—This vessel has had another accident, this time under peculiar circumstances. She left the dock at Newport on the 22d of July to make some runs over the measured mile. Steam was on all four boilers—pressure 120 pounds—but the after boiler had not been connected at the time of shoving off. Shortly after it was connected a sound was heard on deck as if the safety valves had lifted, but no steam escaped. Immediately thereafter the fire room hatch was opened and two men came up with their clothing ablaze; the rest of the men made their escape through the bunkers. Five men were burned, but none seriously.

Examination of the boiler (Thornycroft) showed that one tube in the upper drum had drawn out, that two more in the same row had started, but were held by the flared end, and that five others had started in, one $3\frac{1}{2}$ inches, and the others a very short distance. Steam did not escape into the fire room, the men being burned by gas, which was driven through the openings in the casing, which failed to close with pressure from the furnace.

Truxtun, Whipple, Worden.—These three destroyers were launched by the Maryland Steel Company at Sparrows Point, Maryland, on the 15th of August.

ENGLAND.

King Edward, Dominion and **Commonwealth.**—Three new battleships, to be laid down immediately, are designed to be the most powerful ships afloat. Few particulars are at hand, but those that follow may be considered as fairly accurate.

Length, feet	420
Beam, feet	75
Draught, mean, feet	26.75
Displacement, tons	16,500
I.H.P.	18,000
Speed for 8 hours, knots	18.5
Armor belt, maximum thickness, inches	9
side, above belt, inches	8 to 7

Battery: Four 12-inch; four 9.2-inch; ten 6 inch.

The disposition of the battery is such that two 12-inch, two 9.2-inch and two 6-inch guns have a fore-and-aft fire.

New Cruisers.—Six improved vessels of the *Monmouth* class (see *Kent*, page 486 of this volume) are to be laid down. They will differ from the *Monmouth* class in having one 7.5-inch gun substituted for two of the 6-inch guns.

In addition to these, two other cruisers of 3,200 tons displacement and 21.5 knots speed are to be built.

Destroyers.—The shipbuilding programme provides for ten destroyers with a speed of 30 knots with bunkers full.

Aboukir.—Another vessel of the *Cressy* class, and, like her, built and engined by the Fairfield Shipbuilding and Engineering Company, has completed her trials with the following results:

Duration, hours	30	26	8
Steam pressure in boilers, pounds	230	248	285
at engines, pounds	...	225	...
Revolutions per minute	74.5	114.25	123.2
I.H.P.	4,591	16,274	21,352
Speed, knots	14.4	20.42	21.6

Bulwark.—A first-class battleship of the *Formidable* class, built at Devonport and engined by Messrs. Hawthorne, Leslie & Co., Newcastle-on-Tyne, has completed her trials. The results were:

Duration, hours	30	30	8
Steam pressure in boilers, pounds	227	257	281
at engines, pounds	223	240	258
Revolutions, mean, per minute	66	101	109.8
I.H.P.	3,174	11,755	15,353
Speed, knots	11.2	16.8	18.15

Cornwallis.—A battleship of the *Duncan* class was launched by the Thames Iron Works on the 17th of July. Her chief characteristics are:

Length between perpendiculars, feet	405
over all, feet	429
Breadth, extreme, feet	75.5
Draught, mean, feet	26.5
Displacement, tons	14,000
I.H.P.	18,000
Speed, knots	19
Coal, at above displacement, tons	900
bunker capacity, tons	2,000
Armor belt, from stem to 140 feet of stern, inches	3 to 7
barbettes, inches	11
deck, inches	2

Battery: Four 12-inch in barbettes, twelve 6-inch in casemates, ten 12-pounders, six 3-pounders, eight .303-inch maxims, two boat and field guns, and four submerged torpedo tubes.

The armor belt extends 5 feet below water and 9 feet above to the height of the main deck. Eight of the 6-inch guns are on the main deck and four on the upper deck.

The engines have four cylinders each, one of $33\frac{1}{2}$, one of $54\frac{1}{2}$ and two of 63 inches diameter, with a stroke of 48 inches, and are designed for 18,000 I.H.P. when running at 120 revolutions per minute. The two main condensers have 19,000 square feet of cooling surface.

There are twenty-four Belleville boilers, containing 1,375 square feet of grate and 43,260 square feet of heating surface, and designed for a pressure of 300 pounds, which is to be reduced to 250 at the engines.

Espiegle.—The trials of this sloop, the first to be fitted with Babcock and Wilcox boilers, have been completed with satisfactory results. There were three trials, the first at about one-fifth power, the second at about four-fifths power, and the third at full power. The latter was attended by two members of the Boiler Committee. The results were:

Duration of trial.	Boilers in use.	I.H.P.	Speed.	Coal per I.H.P.
hours.			*knots.*	
30	2	378	10	1.53
30	4	1,031	12.5	1.55
8	4	1,425	13.5	1.69

The *Espiegle* is a twin-screw, sheathed vessel of the following dimensions: Length, 185 feet; beam, 33 feet; mean draught, 11.25 feet; displacement, 1,070 tons. She was designed for a speed of 13.25 knots on 1,400 indicated horsepower.

She has triple-expansion engines, with cylinders 11½, 18 and 29½ inches diameter, by 24 inches stroke. There are four Babcock & Wilcox boilers, having a combined grate and heating surface of 138 and 4,040 square feet, respectively.

Her battery comprises six 4-inch, four 3-pounders and two 0.45-inch Maxims.

Euryalus.—A first-class sheathed cruiser of the *Cressy* class was launched by Messrs. Vickers, Sons & Maxim, at Barrow, on the 20th of May. The principal features of her design are:

Length between perpendiculars, feet	440
Breadth, feet	69.5
Draught, mean, feet	26.25
Displacement, tons	12,000
I.H.P.	21,000
Speed, knots	21
Coal at above draught, tons	800
Bunker capacity, tons	1,600
Armor belt, 230 feet long, inches	6

Battery: Two 9.2 inch; twelve 6-inch; twelve 12-pounders and five smaller guns.

The armor belt is 11 feet 6 inches deep, of which 5 feet is below water. Armored bulkheads 5 inches thick extend across the ship at the extremities of the side armor, forming with it a citadel or enclosed battery 230 feet long, within which are all the guns, machinery, etc.

The two large guns are being provided by the Vickers Company with mountings, before leaving the Barrow works, and with these it is expected that they will easily maintain a continuous fire of three shots per minute. These gun mountings are of a new type, and are arranged to be worked by hand as well as by hydraulic power. Each mounting is effectively protected by a special steel shield having a weight of 50 tons. The whole revolving weight of the mounting, with its gun, is 120 tons. The *Euryalus* can discharge from those guns firing on the bow or those firing from the stern in each minute three projectiles of

380 pounds, 32 projectiles of 100 pounds and 40 projectiles of 12 pounds, or altogether, 75 projectiles, with an aggregate weight of 4,820 pounds. The broadside fire per minute would be 6 projectiles of 380 pounds, 48 projectiles of 100 pounds, and 140 projectiles of 12 pounds, or altogether, 194 projectiles, with an aggregate weight of 8,760 pounds. The guns are served through armored tubes from a passage under the protective deck.

The main engines each have four cylinders, the high-pressure 36, the intermediate 59 and the two low-pressure cylinders 63 inches diameter, with a stroke of piston of 48 inches, and are designed to run at 120 revolutions per minute at full power.

Steam is supplied by thirty boilers of the Belleville water-tube type, placed in four compartments, which take up 130 feet of the length of the ship. The heating surface is about 41,500 square feet. Coal bunkers are arranged along the sides both below and above the protective deck, as well as across the ship right forward. The *Euryalus* will have four funnels and two masts, with a top on each mast for carrying searchlights (but no guns), and with the usual semaphores. Her complement of officers and men will be 740.

Express.—This destroyer, which was designed for a speed of 33 knots, has had several unsuccessful trials, each one demonstrating the seeming impossibility of reaching her contract speed.

The mean of six runs on the mile, made in June, gave 30.9 knots with 9,250 I.H.P. On her last trial, after running for nearly three hours, the intermediate cylinder of the starboard engine was fractured.

She was built by Laird Brothers, and is of the following dimensions: Length, 227.5 feet; beam, 22 feet; draught aft, 9 feet; displacement, 300 tons. She was expected to make 33 knots with 9,000 I.H.P.

Formidable.—The trials of this battleship of the *Canopus* class have recently been concluded with the following results:

Duration, hours	30	30	8
Mean draught, feet	26.75	27.17	26.33
Revolutions, per minute	65.2	100.95	109.35
I.H.P.	3,262	11,618	15,511
Speed, knots	11.5	16.81	18.13

At the conclusion of the first trial there were a number of leaks in the steam pipe joints, and in the nickel ring joints of her boilers.

She is 400 feet long, 75 feet beam, 26 feet 9 inches mean draught, and of 15,000 tons displacement. Her battery comprises four 12-inch, twelve 6-inch and fourteen small rapid-fire guns. Her machinery was built by Earle's Shipbuilding Co.

Leviathan.—A first-class cruiser of the *Drake* class, and similar to the *Good Hope*, described on page 484 of the current volume, was launched at Clydebank June 3d. The principal features of her design are:

Length between perpendiculars, feet	500
Breadth, extreme, feet	71.25
Draught, mean, feet	26
Displacement, tons	14,160
Weight of hull, armor and backing, tons	8,500
I.H.P.	30,000
Speed, knots	23
Coal at normal displacement, tons	1,250
bunker capacity, tons	2,500

Battery: Two 9.2-inch; sixteen 6-inch; fourteen 12-pounders; three 3-pounders; nine Maxims; two submerged torpedo tubes.

The engines are of the four-cylinder triple-expansion type, each with cylinders 43½, 71 and 81½ inches diameter, and a piston stroke of 48 inches, and are designed for 30,000 indicated horsepower when running at 120 revolutions per minute, with 250 pounds pressure at the engines. There are four main condensers with 32,012 square feet of cooling surface, and two auxiliaries with 3,452 square feet.

The crank shafts are in two interchangeable parts of forged steel, and are 21 inches in diameter outside, with a 9-inch hole from end to end. Each cylinder is supported upon two forged-steel pillars at the front, and at the back upon a strong cast-steel column with cast-iron guide plates attached for the piston rod crossheads. The main bearing frames, to which the columns are fastened at their lower end, are of cast steel, tied together longitudinally by cast-steel distance pieces, the main bearings being of gun metal, lined with white metal. The steam distrib-

uting valves for the high and intermediate cylinders are of the piston type, having adjustable packing rings, and those for the low-pressure cylinders are of the ordinary double-ported flat description, fitted with large relief rings on the back. The valves are actuated by double eccentric link motion, hand and steam reversing gear being fitted.

There are two air pumps for each engine, and they are worked from the main engine crossheads, as is usual in vessels of the British Navy. There are four circulating pumps, each with a capacity of 7,000 gallons per minute.

The boilers are of the Belleville type, forty-three in number, and are arranged in four watertight compartments, there being twelve each in two compartments, eleven in another, and eight in the fourth compartment. The total grate and heating surface are respectively 2,323 and 72,000 square feet. There are four smoke pipes, the tops of which are 90 feet above the grate.

Pandora.—After having new screw propellers fitted, this third-class cruiser was given a full-power trial, lasting four hours, the results being: Steam in boilers, 255 pounds; revolutions, 245; I.H.P., 7,330; speed, 19.72 knots.

She has been upwards of three years under construction.

Sprightly.—A destroyer, sister to the *Lively*, the result of whose trials are given on page 491, has completed her trials, the mean speed being 30.03 knots for three hours.

Sutlej.—A sheathed armored cruiser of the *Cressy* class, built and engined by Messrs. John Brown & Co., Clydebank, completed her engine trials in May. She is of the same dimensions as the *Bacchante*, described on page 483 of the current volume. The results of her trials were:

Duration, hours	30	30	8
Steam pressure in boilers, pounds	280	280	280
at engines, pounds	240	240	240
Revolutions per minute	74.8	...	122
I.H.P.	4,679	16,604	21,261
Speed by patent log	14.03	20.63	21.77

Subsequently, she made a series of progressive trials, and four runs over a deep-sea course, the mean of the latter being 18.129

knots, with 9.755 indicated horsepower and 97.9 revolutions of the engines.

Teal.—One of two light-draught river gunboats built by Messrs. Yarrow and Co. for the British Government, and designed for a speed of 13 knots, when carrying a load of 40 tons, on a mean draught not exceeding 2 feet 3 inches. She is 160 feet long and 24 feet 6 inches beam, and has been built in floatable sections.

The hull is composed entirely of galvanized steel, and is subdivided into twelve watertight compartments. The main deck is of steel, and is covered with corticene. The upper deck, or battery deck, extends for about half the length of the vessel. Above this is the awning deck, from which are swung the hammocks for the accommodation of the troops. Protection is afforded at the sides of the vessel by chrome-steel plates. These are of sufficient thickness to resist rifle fire pointblank at close quarters. This armor protects the machinery and cabins; chrome-steel plates also form the bulwarks round the battery deck. Forward, on the battery deck, there is a conning tower, which is also rifle proof.

There are two sets of compound surface-condensing engines, with a speed of about 300 revolutions per minute, and two Yarrow water-tube boilers, of the usual straight-tube type made by this firm and designed for burning wood. The system of propulsion adopted by Messrs. Yarrow in this case was that of twin screws revolving in tunnels of a special design. By so placing them, a large diameter of propeller is made possible, without the tips of the blades passing below the bottom of the hull as they revolve; and thus the screws are not liable to be damaged if the boat runs on to a sandbar. Moreover, they can be brought nearer the surface of the water without losing efficiency by drawing down air; and, indeed, the result of the trial shows a good propulsive result. With this system, too, the propellers are very accessible. Doors are placed at the crown of the tunnels, which rise above the level of the surrounding water, and by removing these the screws can be examined or removed without difficulty while the vessel is afloat. The advantage of carrying out these

operations without docking the boat or putting her ashore will be apparent, specially in a new country.

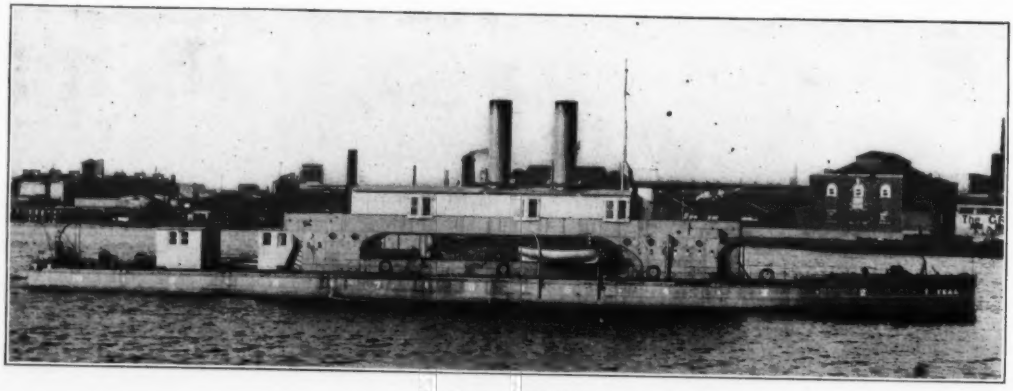
The space available in these little vessels has been skilfully utilized for the accommodation of officers and crew. The former are berthed in well-fitted cabins between the main and battery decks; the armor protection being loopholed for rifle fire. Forward there is a cabin divided to form a wardroom and commander's cabin; this is fitted for three officers. Aft of this there is a cabin which will accommodate eight petty officers. The arrangements for the crew are made for natives, and there is a specially-fitted sick bay. The magazines are placed below, ammunition hoists passing through the cabins, so that there is direct communication, under cover and protected from shot by the cabin plating, between the magazine and the battery deck.

OFFICIAL TRIAL OF H. M. GUNBOAT *TEAL*, AT THE ADMIRALTY MEASURED KNOT ON THE THAMES, MAY 24, 1901.

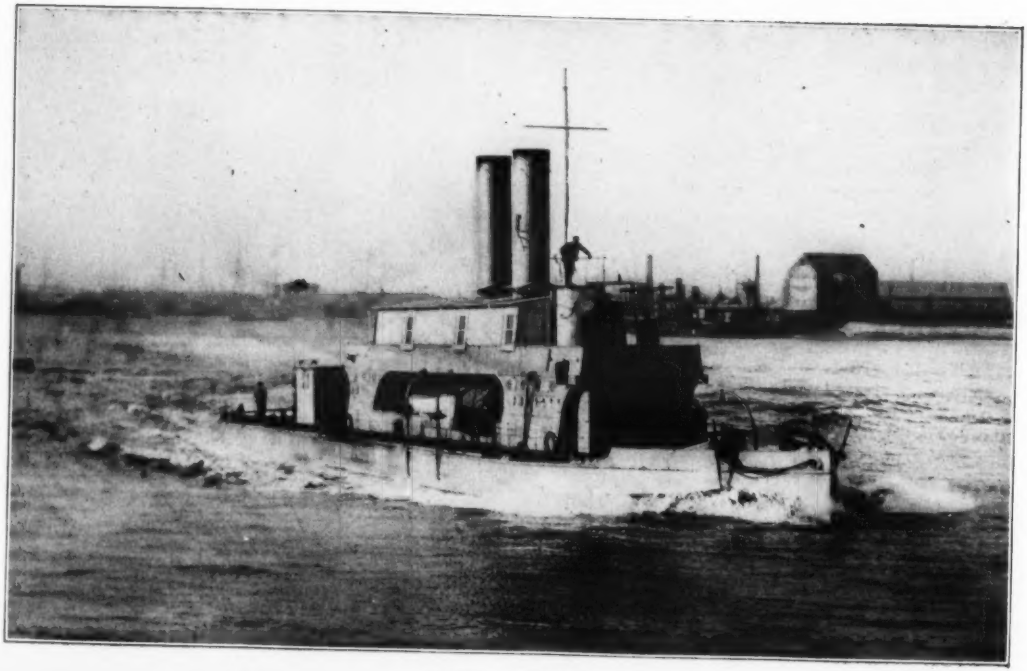
Load, 40 tons. Draught, 2 feet 2½ inches.

Number.	Boiler pressure.	Vacuum.		Air pressure.	Revolutions per minute.	Speed.	Means.	Second means.	Mean speed.
	lbs.	*P.*	*S.*			*knots.*			
1	150	26	26	Nil	278.5	14.938			
							13.059		
2	150	26	25	"	282.9	11.180		13.013	
							12.967		
3	150	26	26	"	281.5	14.754		13.038	
							13.100		13.045
4	150	25½	26	"	282.6	11.465		13.035	
							12.961		
5	150	25½	26	"	284.3	14.458		13.095	
							13.220		
6	150	25½	26	"	289.5	12.000			
Mean.	150	25¾	26	Nil	Mean of means of revolutions, 282.9				

After the six runs on the measured mile a three hours' trial was proceeded with, the mean revolutions being 282.6, equal to 13.033 knots, as the mean speed for the three hours. During one hour wood fuel only was used, and forced draft was not resorted to, the fan being kept slowly revolving for the sake of ventilation only.



H. M. S. "TEAL."



H. M. S. "TEAL."

The vessels have square sterns, and, in order to insure quick maneuvering powers, there are four rudders which can be actuated either by steam or hand gear. There is a fan in the stokehold for forced-draft purposes. This was not in operation during the official trial, but is intended to be used under exceptional circumstances, when only wood of an inferior character is available for fuel.

The other vessel of this type is named *Moorhen*.

Torpedo Boat No. 98.—The trials of this boat, described on page 492 of the last number, gave a mean speed of 25.523 knots for three hours, and 25.79 knots as the mean of six runs on the measured mile.

No. 99.—A duplicate of *No. 98*, completed her trial on the 29th of May, her speed for three hours being 25.06 knots with a load of 42 tons on board.

Vengeance.—The official trials of this battleship, one of the *Albion* class, and built by Messrs. Vickers, Sons & Maxim, of Barrow, have been completed with satisfactory results. Her principal characteristics are:

Length between perpendiculars, feet	390
Breadth, extreme, feet	74·5
Draught, forward and aft, feet	26
Displacement, tons	13,075
Coal at normal draught, tons	800
Bunker capacity, tons	1,600
Armor, belt and casemate, inches	6
barbettes, inches	12

Battery: Four 12-inch in barbette; twelve 6-inch in casemates; twelve 12-pounders; six 3-pounders and fourteen machine guns.

There are two three-cylinder triple-expansion engines, with cylinders 30, 49 and 80 inches diameter and 51 inches stroke of piston. Steam is supplied by twenty Belleville boilers of the economizer type, the working pressure being 300 pounds per square inch reduced to 250 pounds at the engines. The grate surface is 1,050 and the heating surface 33,793 square feet, of which 12,011 square feet is in the economizers.

The results of her trials at one-fifth, four-fifths and at full power are given on the next page. The mean draught was 26 feet.

Duration, hours	30	30	8
Steam pressure in boilers	254	264	298
Steam pressure at engines	243	245	249
Revolutions, mean	66	102.22	110.65
I.H.P.	2,885	10,387	13,852
Speed by patent log	11.35	17.49	18.5

The *Vengeance* was laid down August 23, 1897.

Victoria and Albert.—After many alterations designed to make her seaworthy and to meet the requirements of King Edward, the royal yacht was recently given a commissioning trial with one-half her boilers in use. It was of two hours' duration, the I.H.P. being 5,200 and the speed 16.2 knots.

Viper.—The turbine propelled destroyer *Viper* has been put through a series of tests covering a period of three weeks, for the purpose of instructing her crew and testing her endurance and speed under service conditions. During the first week the speed was low, the highest being about 18 knots; during the second week endurance runs were made at speeds running as high as 25 knots, and during the third week speed runs, the highest reached for one hour, with all stores on board, being 30½ knots.

Upon the completion of these trials, she was to have had coal and water consumption trials in competition with the Thornycroft destroyer *Albatross*, but as she was to take part in the naval maneuvers these trials were unfortunately postponed, and will probably be made with the *Cobra*, as the *Viper* was wrecked on one of the Channel islands during a fog, and is a total loss. She was chasing destroyers of the opposing fleet at the time, and as soon as she struck fired signals of distress, but the other vessels did not heed them, believing that the firing was part of the maneuvers. The crew did their utmost to save the vessel, but a racing tide caused the anchor cables to part and compelled the crew to abandon her in small boats. A French fishing smack, acting as a pilot, helped the crew to reach the shore. The *Viper* was running at 22 knots when the fog set in. She was then eased down to 16 or 17 knots and was running at that speed when she struck. Later,

when her cables parted, her stern smashed on the rocks. Subsequently she parted amidships.

FRANCE.

Chateaurenault.—For some time this *croiseur-corsaire* has been making preliminary trials of her machinery, which have been attended with varying results. Her official trial, early in August, was brought to an end on account of hot bearings.

Dupetit-Thouars.—An armored cruiser of the *Gueydon* and *Montcalm* class, was launched at Toulon on the 5th of July. Her particulars are:

Length, feet	459.33
Beam, feet	63.98
Draught, aft, feet	24.61
Displacement, feet	9,517
I.H.P	19,600
Speed, knots	20
Bunker capacity, tons	1,000
Armor, belt, complete, inches	5.90
along cofferdams, inches	3.93

Battery: Two 7.6-inch guns in turrets; eight 6.48-inch in casemates; four 3.93 with semi-circular shields; sixteen 47-mm., and six 37-mm.; four torpedo tubes.

Her machinery consists of three sets of triple-expansion engines, steam for which is supplied by Belleville boilers.

Iéna.—The trials of this battleship, which were noted on page 498 of the current volume of the JOURNAL, have been supplemented by another, which was quite satisfactory, the results being: Speed, 18.2 knots; I.H.P., 16,500; revolutions per minute, 126.

Jeanne d'Arc.—The first of the official trials of this armored cruiser were brought to an inglorious end, and she had to be towed into port on account of injury to her boilers, due to a defect in the feed. No further details have been published. She has Guyot-Du Temple boilers.

She has been designed for a speed of 23 knots, and is of the following dimensions: Length, 475.73 feet; beam, 62.34 feet; mean draught, 26.58 feet; displacement, 11,270 tons.

Naiade, Protée, Lynx, Ludion.—Four of the seven new

submarine boats that are to be built at Cherbourg. Their dimensions are:

Length, feet	77.1
Beam, feet	7.41
Displacement, tons	68

Their motive power will be wholly electric, supplied by accumulators.

Siroco.—A seagoing torpedo boat of 180 tons displacement has been completed by Normand. She is 147.64 feet long and draws 8.53 feet aft. She has heavy plates (.94 inch) worked along her machinery spaces for protection, and mounts two 47-millimeter guns and three torpedo tubes. Her contract speed is 26 knots.

The engines are twin-screw triple-expansion, and have been designed for 4,200 I.H.P.

Her first official trial had to be stopped on account of a hot crosshead, the speed at the time being 25 knots, and her second one on account of the state of the sea, and also because the grate bars in one boiler came down. On the third trial she made an average speed on the measured base of 28.727 knots with 355 revolutions of the engines.

The **Mistral**, a duplicate of the *Siroco*, was launched at Havre on the 4th of May.

Typhon.—A boat of 185 tons displacement, similar to the *Siroco* and *Mistral*, has been launched at Havre. She is 147.64 feet long and 16.73 feet beam.

GERMANY.

Ariadne.—A vessel of the same size as the *Niobe*, described on page 297 of the current volume, has completed her trials with the following results:

Duration of trial, hours	6
Mean draught, feet	15.32
Air pressure in inches of water	1.7
I.H.P.	8,827
Revolutions per minute	168
Speed, knots	22.18

The pitch of her screws is 16.4 feet.—"Marine Rundschau."

Kaiser Barbarossa.—A battleship of the *Kaiser* class, built and engined by F. Schichau, Elbing, has completed her trials. Her principal dimensions are:

Length between perpendiculars, feet	377.30
Breadth, extreme, feet	66.93
Draught, mean, feet	25.59
Displacement, tons	11,233
I.H.P.	13,000

She has three triple-expansion engines, each of the same size, with cylinders 35.4, 57.5 and 61.4 inches diameter and 37.4 inches stroke, designed to work at 110 revolutions per minute. The valve gear is of the radial type.

Steam is furnished by six single-ended cylindrical boilers, placed in two after compartments, and six Thornycroft boilers in two forward compartments, all working under a pressure of 192 pounds per square inch. The grate and heating surfaces are:

	Cylindrical boilers.	Thornycroft boilers.	Total.
Grate surface, square feet	505.92	413.35	919.27
Heating surface, square feet	16,792	23,929	40,721

The wing screws are three-bladed, 14.76 feet diameter with a mean pitch of 19.68 feet, and the center screw four-bladed, 13.78 feet diameter with a mean pitch of 19.77 feet.

The official endurance trial, of 50 hours' duration, took place from the 25th to the 27th of June, the mean results being:

Mean draught at beginning, feet	25.66
end, feet	24.47
I.H.P.	7,360
Revolutions per minute	94
Coal per I.H.P., main engines	1.83
Speed, knots	15.5

The 6-hour full-speed trial was run on the 5th of July, with the following results:

Mean draught at beginning, feet	25.62
end, feet	25.36
Air pressure, water-tube boilers, inches	2.05
cylindrical boilers, inch	.45
I.H.P.	13,940
Revolutions per minute	112.8
Speed, knots	18

Panther.—This little gunboat was launched on the 1st of April. Her principal features are:

Length, feet	203.42
Beam, feet	29.86
Draught, mean, feet	10.83
Displacement, tons	899
I.H.P.	1,300
Speed, knots	13
Bunker capacity, tons	120

Battery: Four 3.46-inch and eight Maxims.

Prinz Adalbert.—An armored cruiser was launched from the Dockyard at Kiel on the 22d of June. She is of the following dimensions:

Length between perpendiculars, feet	393.7
Beam, feet	64.46
Draught, mean, feet	24
Displacement, tons	8,870
I.H.P.	15,000
Speed, knots	20
Coal at normal draught, tons	950
bunker capacity, tons	1,500
Armor belt, complete, inches	3.15 to 3.94
citadel, 164 feet long, inches	3.94
protective deck, inches	1.57 to 2.75
splinter deck, inches	1.18
conning tower, inches	5.98
turrets, inches	5.90

Battery: Four 8.27-inch in two turrets; ten 5.9-inch; twelve 3.46 inch; ten 37-mm., and four torpedo tubes.

The machinery consists of three sets of four-cylinder triple-expansion engines, in three separate compartments, and of fourteen Dürr boilers.

Wettin.—A battleship of the *Wittelsbach* class was launched by Schichau and Co., Dantzig, on the 6th of June.

Her principal characteristics are:

Length between perpendiculars, feet	393.7
over all, feet	413.4
Breadth, exteme, feet	68.24
Draught, mean, feet	24.93
Displacement, tons	11,800
I.H.P.	15,000

Speed, knots	19
Coal, normal, tons	650
bunker capacity, tons	1,000
Armor, complete belt, inches	3.94 to 8.86
deck, slope, inches	2.95
flat, inches	1.57
turrets, inches	9.84
citadel and 5.9-inch gun positions, inches	5.51

Battery: Four 9.45-inch in turrets forward and aft; eighteen 5.9-inch; twelve 3.46-inch; twelve 37-millimeter, and six torpedo tubes, two above water and four submerged.

The engines are vertical, triple-screw, triple-expansion, each in a separate compartment. The boilers are a combination of Scotch and of the Thornycroft-Schultz type, there being 6,000 indicated horsepower in the former, and 9,000 in the latter with 24,758 square feet of heating surface.

This class of vessels is considered a distinct improvement on the *Kaiser* class, as they have a complete belt of Krupp steel, whereas the *Kaisers* have unprotected ends. They also have an armored citadel in which are mounted eight of her 5.9-inch guns. Two others are placed in casemates abaft the citadel, and the remaining eight in single turrets on the upper deck, four in broadside above the citadel, two in broadside abaft the forward 9.45-inch turret, and the remaining two forward of this turret and near the center line of the ship.

Zaehringen.—Another battleship (*E*), of the *Wittelsbach* class and of the same dimensions as the *Wettin*, was launched on the 12th of June from the Germania Works, Kiel.

HOLLAND.

Rindjani.—This boat was built by Yarrow & Co., and is similar in all respects to the *Pangrang* and the *Ophir*.

About half an hour after being launched she left the builders' works for a series of progressive trials, the results of which are given in the accompanying table. Her draught at starting was 3 feet 9 inches forward, 4 feet 7½ inches aft, giving a mean of 4 feet 2¼ inches, the total load being 49.5 tons. Upon completion of the progressive trials six runs were made at full speed, and the vessel run at full speed for some time afterwards. The

coal burned throughout the trial was 7½ tons, and the draught upon her return 3 feet 6 inches forward, 4 feet 7 inches aft; mean, 4 feet ½ inch.

Steam pressure.			Vacuum.	Air Pressure.	Revolutions per minute.	Speed.	Means.	Second Means.	Slip.
Boiler.	Engine.	H.P. steam chest.							
lbs.	*lbs.*	*lbs.*	*ins.*	*ins.*		*knots.*	*knots.*	*knots.*	*p. c.*
					298.2	21.052			
145	142.5	130	23.1	.75	301.5	18.947	19.999	...	15.5
				Progressive-Speed Trials.					
					311.5	21.686			
155	148.5	144	23	.65	313.7	20.111	20.898	...	15.3
					331.5	23.684			
170	161.5	156.5	23	.83	329.2	21.951	22.817	...	12.4
					336	24.000			
180	165.0	160	22.7	.875	341	22.785	23.392	...	12.4
					342.2	24.161			
190	166.5	160.5	23	1.86	353.1	24.161	24.161	...	11.9
				Full-Speed Trials.					
					363.4	25.532			
200	181.5	176.5	22.8	2.0	366.7	25.175	25.353	25.398	
					368.5	25 714	25.444	25.579	
200	188.3	180	23.2	2.25	369.8	25.714	25.714	25.714	
					370.3	25.714	25.714	25.668	
200	190	183.7	23	1.4	372.3	25.532	25.623		
				Means of Six Miles.					
200	186.6	180	23	1.9	Mean of means—revs., 368.7; speed, 25.590 knots; slip, 12.1 p. c.				

Pangrang.—A further trial of this boat, mentioned on page 502, has been made to determine the increase in speed that can be obtained by using oil as fuel, in addition to coal, the trial being essentially the same as that described for the sister boat *Ophir*. The results of these trials were :

	Coal only.	Oil and coal.
Steam pressure in boilers	150	180
first receiver	54	64
second receiver	5.5	9
Vacuum	23.5	23.2
Revolutions per minute	340	365
Speed	24.5	26.5

The oil is stowed in a tank on deck holding 1,050 pounds, and is sprayed by steam.

ITALY.

Agordat.—The trials of this torpedo cruiser, built at Castellamare, were completed in March. The principal characteristics of her design are:

Length between perpendiculars, feet	287.4
Breadth, extreme, feet	30.51
Draught, mean, feet	10.33
Displacement, tons	1,313
I.H.P.	7,500
Speed, knots	21

Her machinery was built by Messrs. C. and T. T. Pattison, Naples, and consists of twin-screw triple-expansion engines and Blechynden boilers. The engines have each four cylinders, whose diameters are 28.35, 39.37 and 48.03 inches, and stroke 23.62 inches, and were designed for a working pressure of 180 pounds. Piston valves are used for the high-pressure, and slide valves for the intermediate and low-pressure cylinders. The boilers are eight in number, in two groups of four each, one forward and the other aft of the engines, and are designed for a pressure of 200 pounds. Those of each group are in pairs, back to back. The total grate and heating surface are respectively 376.75 and 20,495 square feet.

The screws are 10.16 feet diameter and 12 feet pitch.

The weight of machinery is 285 tons.

The contract required that she should maintain 7,500 I.H.P. at sea for three consecutive hours, during which the air pressure should not exceed 3 inches; and a similar trial of six hours' duration, with one-half inch air pressure, during which the I.H.P. was to be 4,400, and the coal expenditure not more than 2 pounds per I.H.P.

The results of these trials were:

Date	Feb. 11.	Mar. 6.
Duration, hours	3	6
Draught, mean, feet	9.78	10.01
Displacement, tons	1,200	1,246
Steam pressure in boilers, pounds	203	169
at engines, pounds	160	155
Air pressure, inches	2.2 to 3	0.48
Revolutions per minute	232	190
I.H.P.	8,433	4,606
Speed, knots	22.2	18.8
Slip, per cent	12.6	9.5
Coal per I.H.P.	...	2.08

—"Rivista Marittima."

Ammiraglio di Saint Bon.—This battleship, which was launched in 1897, completed her trials in April last. The principal particulars of her design are:

Length between perpendiculars, feet	344.5
over all, feet	365.33
Breadth at water line, feet	68.94
Draught, mean, feet	24.77
Displacement, tons	9,750
I.H.P.	13,500
Speed, knots	19
Water-line plane, square feet	17,632
Immersed midship section, square feet	1,536
Armor, belt, inches	11.02
redoubt and bulkheads, inches	5.90
barbettes, inches	6.30
casemates, inches	6

Battery: Four 10-inch in pairs in turrets forward and aft; eight 6-inch in casemates; eight 4.7-inch; eight 57-millimeters and ten 37-millimeters; 4 torpedo tubes.

She has one military mast and two smoke pipes.

Her machinery, supplied by Ansaldo and Co., Genoa, consists of twin-screw triple-expansion engines, steam for which is supplied by twelve cylindrical boilers arranged in four boiler rooms, two of which are forward and two aft of the engines.

On her full-speed trial she made 19.2 knots with 104 revolutions of her engines.

Nembo.—The first of four torpedo-boat destroyers of the Thornycroft type was launched by Messrs. Pattison, at Naples, on the 18th of May. Her principal characteristics are:

Length between perpendiculars, feet	208
Breadth, feet	19.6
Draught, load, aft, feet	7.5
forward, feet	6.33
Displacement at above draught, tons	330
I.H.P.	6,000
Speed, knots	30

Armament: One 3-inch and five 6-pounder guns; two torpedo tubes.

The engines are twin-screw, vertical, triple-expansion, with four cylinders each, and the boilers, three in number, of the Thornycroft type.

The bunkers hold 80 tons of coal.

Regina Margherita.—This first-class battleship was launched at Spezia on the 30th of May. The following particulars of her are from "Rivista Marittima."

Length between perpendiculars, feet	426.5
Breadth, extreme, feet	78.2
Draught, mean, feet	27.0
Displacement, tons	13,426
I.H.P.	19,000
Speed, knots	20.5
Coal, normal, tons	1,000
bunker capacity, tons	2,000
Armor belt, for length of redoubt (262 feet), inches	5.9
2d zone, from W.L. to upper deck, inches	5.9
turrets, inches	7.87
bulkheads, inches	7.87
casemates for four 8-inch guns	5.9
conning towers (2)	5.9

Battery: Four 12-inch in pairs, in turrets; four 8-inch R. F. in casemates; twelve 6-inch in broadside on battery deck; sixteen 3-inch on upper deck; eight 47-mm.; four torpedo tubes, two above water and two submerged.

The 8-inch guns are mounted singly on the upper deck, and supported at the corners of the redoubt. The water-line belt is complete, but its thickness is reduced forward and aft of the limits of the redoubt.

The engines are twin-screw triple-expansion, with four cylin-

ders, and the boilers, twenty-eight in number, of the Niclausse type. The boilers are forward of the engines in three principal compartments, each divided by a longitudinal bulkhead. The engine cylinders are 37, 60 and 69.3 inches diameter with a piston stroke of 47.25 inches. The revolutions are expected to be 120 when the engines are developing 19,000 indicated horsepower. The grate and heating surface are respectively 1,550 and 50,312 square feet. There are twelve fans for forced draft; they are operated by electric motors, and are intended to maintain an air pressure of .4 inch of water.

The electric plant is contained in two stations, each having generators of 200 kilowatts output.

The distribution of weights is:

Hull and equipment, tons	6,195
Armored protection, tons	3,155
Armament, tons	1,473
Machinery, tons	1,603
Coal, tons	1,000
Total	13,426

Her speed with natural draft is expected to be 19 knots with 16,000 indicated horsepower.

She will carry a complement of 30 officers and 625 men.

PORTUGAL.

Rainha Amelia.—The trials of this twin-screw cruiser have been satisfactorily completed. The results are:

	Natural draft.	Forced draft.
Duration, hours	5	3
Steam pressure	160	170
I.H.P.	3,088	5,396
Revolutions per minute	170	200
Speed, knots	17.1	20.6

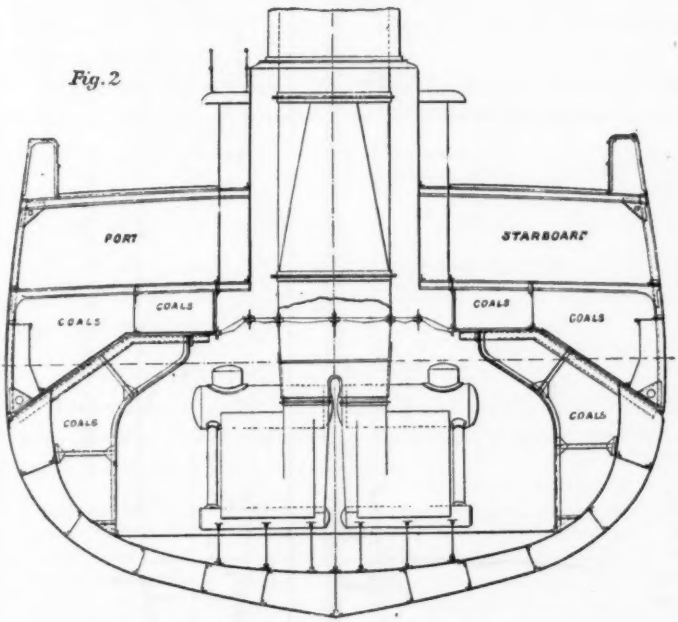
Following the natural-draft trial, she ran for 24 hours at 162 revolutions, giving a speed of 15.75 knots.

She is 246 feet long, 36 feet beam, and, on a mean draught of 14.67 feet, has a displacement of 1,660 tons. Her battery comprises four 5.9-inch, two 3.9-inch and six smaller guns.

RUSSIA.

Bogatyr.—The illustrations of this ship, a description of which appeared on page 511 of the current volume, are from "Engineering," and give a good idea of her general appearance and the distribution of her battery. Four others have just been ordered built, one at Windau, another at Libau, a third at Nicolaief, and a fourth at Sebastopol.

Fig. 2

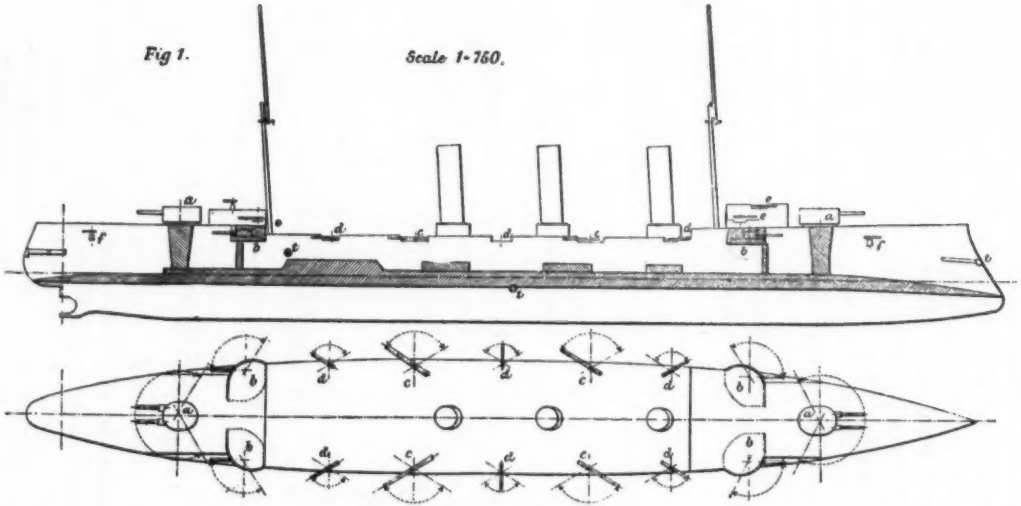


MIDSHIP SECTION, "BOGATYR."

Boyarin.—On the 8th of June there was launched from the yard of Burmeister and Wain, Copenhagen, a Russian cruiser, the principal features of whose design are:

Length, feet	355
Beam, feet	41.5
Draught, mean, feet	16

Fig 1. *Scale 1-760.*



RUSSIAN CRUISER "BOGATYR."

Displacement, tons	3,200
I.H.P.	11,500
Speed, knots	22
Coal at normal draught, tons	400
bunker capacity, tons	600

Battery: Six 4.7-inch, eight 47-mm. and five smaller guns and five torpedo tubes.

Her protection consists of a curved deck 2 inches thick on the slope and 1¼ inches on the flat.

The engines are four-cylinder triple-expansion, steam for which is furnished by sixteen Belleville boilers placed in three water-tight compartments.

Forel and **Sterliade.**—The following are the results of the trials of these two Normand-built destroyers, carrying a load of 70 tons.

	Forel.	*Sterliade.*
Speed for one hour, . . .	27.017	27.381
Speed for five hours, . . .	22.905	22.510

These vessels are 183.73 feet long, 19.68 feet beam, 9.84 feet draught aft, and of 312 tons displacement. Their engines were designed for 4,750 I.H.P.

TURKEY.

It is reported that the Messrs. Cramp and the Elswick Company have been awarded contracts to build each a protected cruiser to have the following characteristics:

Length between perpendiculars, feet	328
Breadth, extreme, feet	42
Draught, mean, feet	16
Displacement, tons	3,250
I.H.P	12,000
Speed, knots	22

Battery: Two 6-inch; eight 4.7-inch; six 47-mm. and six 37-mm.

The engines will be of the triple-expansion type and the boilers of the Niclausse type. They are to be completed in twenty-two months.

MERCHANT STEAMERS.

Cap Verde.—A single-screw freight and passenger steamer built by the Flensburg Shipbuilding Company. The following particulars of her hull and machinery are from "Zeitschrift des Vereines Deutscher Ingenieure."

Length between perpendiculars, feet	410
Breadth, extreme, feet	47.9
Depth amidships, feet	32.8
at sides, feet	32
Deadweight capacity, tons	6,550
Mean draught, including keel, feet	24.61
Speed at mean draught of 22 feet, knots	12.5
I.H.P.	2,800
Revolutions per minute	68
Bunker capacity, tons	900

Her engines are of the quadruple-expansion type, with cylinders 25, 35½, 53 and 77 inches diameter by 54 inches stroke; the H.P. and first I.P. are jacketed. The valves are of the piston type for the high-pressure, and flat slide for the other cylinders, and are operated by Stephenson link motion. The crank shaft is in two sections, the H.P. and I.P. being on one section, and the two I.P. on the other.

The angles between the cranks are: H.P. and 1st I.P., 73 degrees; 1st I.P. and L.P., 99 degrees; L.P. and 2d I.P., 104 degrees; 2d I.P. and H.P., 84 degrees. The crank shaft is 15 inches diameter, the thrust shaft 15 inches, the line shaft 14⅝ inches, and the propeller shaft 16 inches.

The condenser contains 2,680 tubes ¾-inch diameter; the cooling surface is 4,200 square feet. There is also an auxiliary condenser with 753 square feet of surface. The air pump is of the Edwards type, 29 inches diameter and 32 inches stroke, and is worked from the 1st I.P. crosshead, as are also two feed and two bilge pumps, the former 4½ and the latter 5 inches diameter, and both 32 inches stroke.

There are two boilers 12.25 feet diameter and 20.7 feet long, each containing four Morison suspension furnaces 40½ inches diameter, and designed for a working pressure of 213 pounds per square inch. Each boiler contains 452 tubes 2¾ inches diameter, spaced 4 inches horizontally and vertically.

There is, in addition, an auxiliary boiler of the same diameter as the main boilers, containing 226 tubes. The grate and heating surface of the main boilers are, respectively, 142 and 6,114 square feet, and of the auxiliary 35.5 and 1,608 square feet, making a total of 177.5 square feet of grate and 7,722 of heating surface.

The screw has a steel hub and four bronze blades. Its diameter is 18.5 feet, the pitch 18.5 feet, and the projected area 76.1 square feet.

Besides this machinery, she has the usual outfit of independent feed, ballast and fresh-water pumps, two dynamo engines, turning engine, etc.

City of Erie-Tashmoo Race.—On the 4th of June a most exciting race was run on Lake Erie between the side-wheel steamers *City of Erie* and *Tashmoo*, the course being 94 statute miles in length, between Cleveland and Erie. The *City of Erie* is a freight and passenger boat of much fuller lines than the *Tashmoo*, which was designed for passenger service. Both were built by the Detroit Shipbuilding Company, who also built the machinery for the *Tashmoo*, that for the *City of Erie* having been built by the W. & A. Fletcher Company, Hoboken, New Jersey. The race was won by the *City of Erie* by 45 seconds.

The following data of the vessels and of their machinery, with the data taken during the race, are rearranged from the data published in the "Marine Review," which was supplied by Messrs. C. B. Calder and A. George Mattsson, representatives of the Detroit Shipbuilding Company, who were on the *City of Erie* and *Tashmoo* respectively.

	City of Erie.	*Tashmoo.*
Length over all, feet	324	308
on keel, feet	314	300
Beam, feet	44	37.5
Breadth over guards, feet	77.2	69
Depth, feet	18	13.5

	City of Erie.	*Tashmoo.*
Draught, forward, feet	9.75	8.12
aft, feet	10.83	8.46
mean, feet	10.29	8.29
Displacement, tons	2,233	1,224
Trial load, tons	250	60
Wetted surface, square feet	12,776	8,976
Prismatic coefficient	.603	.584
Engine, type	Compound, beam.	Triple, inclined.
Cylinder, H.P. diameter, inches	52	33
I.P., diameter, inches	...	51
L.P., diameter, inches	80	82
stroke, inches	H.P., 96 / L.P., 144	72
Air pump, diameter, inches	52	45
stroke, inches	45	24
Feed pump, independent	16×11×14	14×8×12
Fire pump	14× 8×10	10×6×10*
Boilers, cylindrical, number	6	5
diameter, feet	12.5	11.08
length, feet	11.75	3 of 11.33 / 2 of 22
furnaces, diameter, inches	46	42
grate length, feet	5.5	6
surface, square feet	252	294
heating surface, square feet	11,580	8,750
Forced draft system	Howden.	None.
Steam pressure, pounds	130	170
Blowers, number	2	...
diameter, inches	66	...
discharge, inches	34 × 34	...
engine, inches	7 × 7	...
Heater, diameter, inches	25	25
length, feet	10.17	9.5
tubes, diameter, inches	1½	1½
length, feet	8	7
surface, square feet	302	282
Wheels, diameter over buckets, feet	28.5	22.42
trunnions, feet	25.17	19.08
buckets, number	11	9
width, feet	4	3.75
length, feet	12	12
dip, feet	5.17	4.75

* Duplex.

The following are the data of the run:

Steam pressure, pounds	120.4	175*
Vacuum, inches	23.5	22
Air pressure, inches	5 max.	...
Revolutions per minute	33.25	40.08
M.E.P. in H.P. cylinder, pounds	58.4	...
I.P. cylinder, pounds	...	...
L.P. cylinder, pounds	36.6	...
referred to L.P., pounds	53.07	...
I.H.P., H.P. cylinder	2,004.6	...
L.P. cylinder	4,467.7	...
total	6,472.3	3,400
I.H.P. per square foot of grate	25.68	11.58
H.S. per I.H.P., square feet	1.79	2.57
I.H.P. per 100 square feet of wetted surface, pounds	50.66	39.1
Distance, in statute miles	94	94
Speed, in statute miles	21.76	21.70
in knots	18.899	18.847
Slip of wheel over bucket, per cent	35.65	32.2
Depth of water in fathoms, start	9	9
minimum	7	7
maximum	12	12
average	10	10
Admiralty coefficient	178.2	225

Deutschland.—This vessel has again made a remarkably fast passage from New York to Plymouth, covering a distance of 3,082 miles in 5 days 11 hours and 5 minutes, or at the rate of 23.51 knots for the distance. Her highest day's run was 557 miles. Although this is not equal in point of time to a former run, 5 days 7 hours and 31 minutes, it is a record for speed, the speed on this latter run having been 23.36 knots.

On the voyage from Cherbourg to New York, made the last week in July, she made the greatest daily run on record—601 miles.

El Dia.—This vessel, built for the Morgan line by the Newport News Shipbuilding and Drydock Company, was launched on the 16th of May. She was designed by Mr. Horace See, and is of the following dimensions:

* L.P. passover valve half open during last one and a-half hours.

Length between perpendiculars, feet	380.7
over all, feet	406
Breadth, molded, feet	48
Depth, molded, to awning deck, feet	33.75
Gross tonnage	4,665
Net tonnage	2,905

She has two pole masts fitted with the usual cargo booms. There are three continuous decks and a partial deck at the forward end of the forehold. There are forward and after deck houses, as is usual in the Morgan liners, connected by a flying bridge.

The engines are of the triple-expansion type, with cylinders 33, 52 and 84 inches diameter and 54 inches stroke. Piston valves are used on all cylinders, there being one each for the high and intermediate, and two for the low-pressure cylinder, all operated by radial gear of the Marshall-See type. The crank shaft and crank pins are 16½ inches diameter and the pins 16½ inches long, and the crosshead pins 8 inches diameter and 9½ inches long. The air pump is 32 inches diameter and 25 inches stroke, and the cooling surface in the condenser, 6,400 square feet.

There are three double-ended boilers 13 feet 10 inches diameter and 20 feet 6 inches long, designed for a working pressure of 180 pounds, each having six corrugated furnaces 43 inches inside diameter. The grate surface is 400 and the heating surface 10,650 square feet.

El Siglo.—A sister vessel to the *El Dia* was launched on the 27th of July.

Haverford.—The following additional particulars of the machinery of this vessel, described on page 534, are from "Marine Review."

There are two double-ended and two single-ended boilers. The double-ended boilers are 16 feet 8 inches mean diameter by 19 feet long, and the single-ended boilers 16 feet 8 inches mean diameter by 11 feet long. Each of the double-ended boilers has eight furnaces and each single-ended boiler four, being twenty-four in all. These furnaces are of the Morison suspension type, 34½ inches inside diameter, with the back ends made on the

Gourlay-Stephen principle, whereby a defective furnace can be taken out of the boiler without disturbing any other part of it. The end plates of the boilers are all flanged inwards to meet the shell and the furnaces.

Each opposite pair of furnaces in the double-ended boilers has a common combustion chamber; and in the case of the single-ended boilers, each furnace has a separate combustion chamber. The combustion chambers are all securely stayed to the boiler shell and ends. The combustion chamber tops in the single-ended boilers are supported by girders in the usual way, while those in the double-ended boilers are supported by stays attached to the shell of the boiler.

The boiler tubes are all of iron, 7 feet 5 inches long between the tube plates and $3\frac{1}{4}$ inches external diameter. The common tubes are No. 7 I.W.G. thick and the stay tubes are $\frac{1}{4}$, $\frac{5}{16}$ and $\frac{3}{8}$ thick, to suit their respective loads. The common tubes have the front ends swelled $\frac{1}{16}$ larger in diameter than the back end, and the stay tubes have been staved up in a hydraulic press till the thickness at the screwed ends is the same at the bottom of the thread as the body of the tube. There is 11 inches clear space between the nests of tubes for access for cleaning. The boilers work under natural draft at a working pressure of 160 pounds per square inch.

King Edward.—This is the name that has been given to the turbine steamer the details of whose construction were referred to on page 434. She was launched by Messrs. Denny Brothers on the 16th of May.

In addition to the details already published, it may be said that she has five screw propellers, one on the center shaft and two on each of the wing shafts. Steam is furnished by one double-ended cylindrical boiler with four furnaces at each end, and working under forced draft on the closed stokehold system. Owing to the limited depth of the vessel, a separate uptake and smoke pipe have been fitted for each end of the boiler. All the auxiliary engines, except the main air pumps, are operated independently of the main engines. The main air pumps are worked by worm gearing from the wing shafts, but there are auxiliary

air pumps actuated by the circulating-pump engines, for clearing the condensers of water when the main engines are not in operation. There is a feed heater which uses the exhaust steam, or steam taken from an intermediate point in the turbines if necessary.

The whole of the handling of the engines is effected by the manipulation of valves in a very simple manner.

The weight of the motors, condensers, with water in them, steam pipes, auxiliaries connected with the propelling machinery, shafting, propellers, etc., is 66 tons.

The trial of the *King Edward* took place on the 26th of June, the mean of several runs over the Skelmorlie mile giving the following results:

Speed, knots	20.483
I.H.P., estimated	3,500
Revolutions of turbines per minute	740
Steam pressure in boilers, pounds	150
Vacuum, inches	26½
Air pressure, inch	1

The weather conditions were favorable. No figures are given for coal consumption.

"Engineering," from which the above data were taken, says:

Still another advantage due to the adoption of this machinery is the noiselessness with which it runs. So far as the turbines themselves are concerned, it is not possible to tell whether they are running or not by placing one's hand on them. There is, however, a very slight vibration that can be felt right astern, and this is due to the propellers. Whether this can be eliminated or not remains to be seen, but certainly no vibration is set up by the main engines themselves. At the bow end motion is similar to that of a fast-sailing yacht; and it might have been better had the main saloon been placed forward instead of aft.

It had been expected that the vessel would be very difficult to bring alongside a wharf, and, judging by experience with torpedo-boat destroyers, the prediction was not unwarranted. This must always be more or less the case with lightly-built vessels having small rise of floor, little lateral resistance, and somewhat high

superstructure. The fine lines of the *King Edward*, with her long bow and lean quarters, however, give a good deal of approximately vertical surface at the ends, and this probably accounts for the ease with which she took Rothsay pier on her first run on her regular route. It is true the day was favorable, there being very little wind, but Rothsay pier is a very difficult one to take, lying right in the bight of a very narrow bay. Moreover, there were several yachts anchored off which hampered the pilot a good deal. In regard to the fine shape of the boat, it may be pointed out that the low center of gravity of the turbine machinery gives good stability without the necessity for a hard bilge or long floor; in fact, this type of machinery lends itself readily to a form of hull conducive to high speed.

Kingstonian.—A single-screw steamer built by Messrs. R. and W. Hawthorn, Leslie and Company, Hebburn-on-Tyne, England, for the Leyland line, and intended for general transatlantic cargo and cattle trade. She is of the following dimensions:

Length, feet	467
Breadth, feet	53.75
Depth, feet	42.58
Deadweight capacity, tons	9,600

There is accommodation for twenty-four first-class passengers in an extensive upper bridge, containing a handsome dining saloon panelled in light pollard oak, smoke room, etc. This upper bridge forms a magnificent promenade, the forward end of which is enclosed in such a way as to afford shelter to the passengers in heavy weather.

She has in her upper works, where they are completely sheltered from the weather, stalls for about 700 live cattle. Under the upper bridge special stalls will be fitted for horses, and with the necessary accommodation for their attendants. A considerable portion of the 'tween decks will be insulated, and the necessary refrigerating plants fitted to enable large consignments of meat and dairy produce to be dealt with. The vessel is divided into watertight compartments, and these with the four decks laid give a total of sixteen compartments available for various kinds of cargo. In addition to the double bottom, there is a large tank

aft of the machinery space for use as a ballast tank, making the total ballast capacity 2,226 tons. The cargo hatches and the equipment are specially adapted to afford the greatest possible facilities for loading and discharging the exceptionally spacious holds and 'tween decks.

The machinery consists of a set of triple-expansion engines, working at a pressure of 200 pounds per square inch, and capable of maintaining 4,500 horsepower at sea. The sizes of the cylinders are 31, 52 and 86 inches, by 60 inches stroke. Steam is supplied by four large boilers, two of them being double-ended and two single-ended. The boilers are fitted with Henderson's patent automatic self-cleaning furnaces. The usual auxiliary machinery is fitted, comprising feed pumps, evaporator, auxiliary condenser, centrifugal circulating pump and feed-water filter. The shafting is of fluid-compressed steel, and the propeller, four-bladed, has adjustable blades of manganese bronze.

Kumano Muru.—A single-screw mail steamer, built by the Fairfield Shipbuilding and Engineering Company for the Nippon Yusen Kaisha, of Tokio, was launched on the 1st of June. Her dimensions are:

Length over all, feet	415
Breadth, molded, feet	48.5
Depth, molded, feet	30
Gross tonnage, about	4,800

She is of the three-deck type, and will be schooner rigged, with two pole masts. She is constructed with a center through plate keel with side bars to form a bar keel, double bottom on the cellular system, arranged for water ballast, and bilge keels. The hull is divided into watertight compartments by eight steel bulkheads, and the double bottom is closely subdivided by water-tight floors and girders. There is a full poop, long bridge, and top-gallant forecastle, and shade deck extending over the bridge, while large deck houses are fitted on the poop, bridge and shade deck. The boats are stowed on the shade deck, leaving the bridge deck clear for first-class passengers' promenade. The staterooms for first-class passengers are arranged on the upper deck amidships, and the dining saloon, social hall and smoking

rooms fitted up in the houses on the bridge deck. Second-class accommodation is fitted under the poop, with a smoking room in the house on the deck above. Steerage berths are fitted for a limited number of passengers in the forward and after compartments on the main deck.

The propelling machinery consists of one set of triple-expansion engines, having three inverted cylinders working on three cranks. The high-pressure cylinder is 31, the intermediate 51, and the low-pressure cylinder 85 inches in diameter, all adapted for a stroke of 54 inches. The high-pressure cylinder is fitted with a piston valve, the remaining cylinders with slide valves, and all are worked by the usual double-eccentric link-motion valve gear, controlled by a combined steam and hydraulic reversing gear. The crank shaft is in three pieces, each piece being built up and interchangeable, and, together with the thrust and tunnel shafts, is of mild steel. The propeller shaft is of Morison's patent lock-fast iron. The propeller boss is of cast iron, and is fitted with four blades of manganese bronze. The air pump is of the Edwards patent.

Steam will be supplied by three double-ended and two single-ended boilers. Each of the double-ended has six Morison furnaces, and each of the single-ended three, making a total of twenty-four furnaces, all adapted to work at 185 pounds pressure.

A special feature of the vessel is the ventilation and heating and cooling of the cabins, which is on a most elaborate and complete scale. Stewart's patent thermotank system has been adopted for all living spaces, four thermotanks, with the necessary electric fans, etc., being fitted in conjunction with steel trunks led to the various apartments. Each cabin will have its own adjustable louvre, so that the amount of air to be admitted can be regulated to a nicety, and by this means the passengers will be supplied with fresh air heated to a suitable temperature without the discomforts of cold drafts and steam-heating pipes. A further improvement has also been effected by fitting a system of brine pipes from the refrigerating machine connected with the thermotank coils so that the air to be circulated through the cabins may be cooled. By these means the passengers can be supplied with

air either at the natural temperature of the atmosphere or higher or lower, according to the climate in which the vessel may be sailing.

La Savoie.—A sister vessel to *La Lorraine*, built at St. Nazaire for La Compagnie Générale Transatlantique, and intended for the New York-Havre route.

Her principal particulars are:

Length, feet	580.7
Beam, feet	60.2
Depth, feet	39
Draught, load, feet	25.26
I.H.P.	20,000 to 22,000
Speed on mean draught of 22 feet, knots	22
Bunker capacity, tons	3,000
Fresh-water capacity, tons	1,500

She has five decks, is divided into sixteen watertight compartments, and has been constructed with special reference to use as an auxiliary cruiser in time of war, being fitted for mounting a battery of nine 5.67-inch and eight 4.13-inch rapid-fire guns.

She has accommodations for 1,500 passengers. Her crew numbers 372.

She has twin-screw triple-expansion engines, each with four cylinders, the high-pressure being 43.3, the intermediate 68.4, and each of the low-pressure 80.2 inches diameter, with a stroke of piston of 66.93 inches. They were designed for 20,000 to 22,000 I.H.P. when making from 85 to 90 revolutions per minute. There are sixteen single-ended boilers 17.06 feet diameter and 10.83 feet long, designed for a working pressure of 165 pounds. There are four furnaces in each boiler. The grate and heating surfaces are respectively 1,227 and 45,533 square feet. The boilers are worked under forced draft, on the Howden system, there being eight fans 66.9 inches in diameter for this purpose. The screws are 21.52 feet diameter, and have a pitch variable from 25.59 to 27.56 feet.

Lake Manitoba.—A single-screw steamer built by Messrs. Swan and Hunter, Wallsend-on-Tyne, for the Elder-Dempster line. Her principal dimensions are:

Length, feet	483
Breadth, molded, feet	56
Depth, molded, feet	34.83

Above the upper deck a complete shelter deck forward and aft has been fitted, whilst above that again there is a bridge 162 feet long. Accommodation will be provided for 122 first-class passengers, the dining saloon being at the forward end of the bridge, the staterooms being partly in the bridge and partly in large deck houses on top of the bridge. In these deck houses a very handsome smoke room will be fitted and also a comfortable library. Practically the whole of the space between the upper and shelter decks has been reserved for third-class passengers, the space being sufficient to accommodate 1,250. A large percentage of these will be berthed in four-berth staterooms, the dining accommodation being unusually good, tables and settees being provided in the center of the ship between the staterooms, and there being several pantries and other facilities to provide for the complete comfort of this class of passenger. The third-class passengers will also have a large smoke room, and also a ladies' room. The accommodation for the crew will be forward below the shelter deck, whilst that for the firemen will be on the upper deck amidships, close to the boiler room. The officers and engineers are provided with rooms at the aft end of the bridge. Above the houses on the bridge deck there will be a boat deck carried right across to the full width of the ship.

Her machinery, which was constructed by Messrs. Richardson, Westgarth & Co., consists of a triple-expansion engine having cylinders 23½, 38 and 64 inches diameter by 45 inches stroke, and of five single-ended boilers 15 feet diameter and 11 feet 9 inches long, all constructed for a working pressure of 180 pounds.

Her speed on trial was 12 knots.

Lyra.—A single-screw cargo steamer recently completed by the Maryland Steel Company for the Boston Towboat Company, and similar in general construction to the *Pleiades* and *Hyades* built for the same company. She is intended for general cargo as well as a collier. Her dimensions are:

Length between perpendiculars, feet	330.5
over all, feet	350
Beam, molded, feet	47
Depth, molded, feet	35.5
Net tonnage	3,516
Gross tonnage	4,417
Deadweight capacity on draught of 24.25 feet, tons	6,300
Bunker capacity, tons	633
Water ballast, tons	1,150

She has three complete decks, the lower, main and shelter, the officers' quarters being arranged in a deck house on the latter.

The cargo space is divided into four holds, two of which, those immediately forward and aft of the machinery space, are each about 75 feet in length. Columns built of channels have been used instead of the customary round columns in these two compartments, thus giving more room for the stowage of bulky freight, there being but three of these columns on each side.

The engine is of the usual triple-expansion type, with cylinders 21, 35 and 56 inches diameter by 42 inches stroke, with the air pump worked from the low-pressure crosshead. There are two single-ended boilers 14 feet 6 inches diameter and 10 feet 10 inches long, working under a pressure of 175 pounds per square inch. Each has three corrugated furnaces 45 inches diameter. The grate surface is 146 square feet, and the heating surface 4,380 square feet.

The *Lyra* was completed in a very short time after the signing of contract, a little more than nine months, being somewhat delayed in final completion on account of the strike of machinists.

Peleus and **Tydeus.**—These two single-screw steamers have recently been completed by Messrs. Workman, Clark & Co., Belfast, Ireland, to the order of Mr. Alfred Holt, Liverpool, and are intended for the China trade. They have a two-masted schooner rig, and are of the following dimensions:

Length, feet	452
Breadth, molded, feet	54
Depth, molded, feet	35.25
Gross tonage	7,440

The main holds are practically free from obstructions to the stowage of cargo, as box girders have been substituted for supporting the decks, instead of the usual arrangement of pillars. This system is carried out in the remaining portions of the vessel in a somewhat modified degree. There are four cargo holds and two deep tank compartments, which may be utilized for either cargo or water ballast for trimming purposes. Seventeen winches and twenty-five derricks are provided for the discharge of cargo, one of the derricks being capable of lifting thirty-five tons. The deck erections consist of poop, topgallant forecastle, and a long bridge, on which is placed deckhouses for the accommodation of the captain, officers and engineers. The sternpost and rudder are a special feature, the deadwood at the foot of the sternpost being completely cut away, thus allowing a free run of water to the propeller. A wrought-steel tube forms the sternpost, from which the rudder is hung, and the arch of the remaining portion of the stern frame consists of a steel plate of U section. The rudder is of the balanced type, and is entirely constructed of plates and angles, excepting the upper portion of the stock, which is a forging.

The machinery, which has been constructed by Messrs. Workman, Clark & Co., consists of a powerful set of the triple-expansion engines, having the most modern improvements in auxiliaries, with steam supplied at a pressure of 190 pounds from two large double-ended boilers, fitted with forced draft on the closed stokehold system.

The trials of these vessels gave an average speed of 14 knots on the measured mile.

The accompanying table from the "Marine Review" gives the particulars of eighteen steamers for which the American Shipbuilding Company (consolidated Lake yards) has orders for delivery in the spring of 1902.

PARTICULARS OF EIGHTEEN STEEL STEAMERS UNDER ORDER WITH AMERICAN SHIPBUILDING CO. (CONSOLIDATED LAKE YARDS) FOR DELIVERY IN SPRING OF 1902.

To be built in—	Type.	Dimensions in feet.				Dimension of engines. All triple expansion.
		Over all.	Keel.	Beam.	Depth.	
1 Cleveland	Cargo	436	416	50	28	22, 35, 58 by 40
2 Cleveland	Cargo	436	416	50	28	22, 35, 58 by 40
3 Lorain	Cargo	400	380	50	28	22, 35, 58 by 40
4 Lorain	Cargo	400	380	50	28	22 35, 58 by 40
5 Lorain	Cargo	400	380	50	28	22, 35, 58 by 40
6 Lorain	Cargo	400	380	50	28	22, 35, 58 by 40
7 Lorain	Cargo	400	380	50	28	22, 35, 58 by 40
8 Chicago	Cargo	366	346	48	28	20, 33½, 55 by 40
9 Chicago	Cargo	366	346	48	28	20, 33½, 55 by 40
10 Chicago	Cargo	366	346	48	28	20, 33½, 55 by 40
11 Lorain	Cargo	366	346	48	28	20, 33½, 55 by 40
12 Chicago	Cargo	366	346	48	28	20, 33½, 55 by 40
13 Cleveland	Carge	374	354	48	28	20, 33½, 55 by 40
14 Place not assigned	Cargo	366	346	48	28	20, 33½, 55 by 40
15 Place not assigned	Cargo	366	346	48	28	20, 33½, 55 by 40
16 Detroit	Day *P*	308	300	37–6	13–6	33, 51, 82 by 72
17 Detroit	*P* & *F*	366	350	55	19–6	.....
18 Detroit	*P* & *F*	366	350	55	19–6	.....

P = Passenger. *F* = Freight.

Boilers—dimension in feet and inches.	Draft.	Steam pressure, lbs.	Capacity, gross tons, 18 feet draught.	Value.
1 Two Scotch, 13–2 by 11–6	Ellis & Eaves	170	6,200	$260,000
2 Two Scotch, 13–2 by 11–6	Ellis & Eaves	170	6,200	260,000
3 Two Scotch, 13–2 by 11–6	Howden	170	5,600	240,000
4 Two Scotch, 13–2 by 11–6	Howden	170	5,600	240,000
5 Two Scotch, 13–2 by 11–6	Howden	170	5,600	240,000
6 Two Scotch, 13–2 by 11–6	Howden	170	5,600	240,000
7 Two Scotch, 13–2 by 11–6	Howden	170	5,600	240,000
8 Two Scotch, 12–10 by 13	Natural	170	4,800	220,000
9 Two Scotch, 12–10 by 13	Natural	170	4,800	220,000
10 Two Scotch, 12–10 by 13	Natural	170	4,800	220,000
11 Two Scotch, 12–10 by 13	Natural	170	4,800	220,000
12 Two Scotch, 12–10 by 13	Natural	170	4,800	220,000
13 Two Scotch, 14 by 12	Natural	170	4,900	220,000
14 Two Scotch, 12–10 by 13	Natural	170	4,800	220,000
15 Two Scotch, 12–10 by 13	Natural	170	4,800	220,000
16 Five cylindrical type, 3 single-ended, 2 double-ended	.....	170	.....	275,000
17 Eight Scotch	.....	.....	.....	640,000
18 Eight Scotch	.....	.....	.....	640,000
			78,900	$5,035,000

YACHTS.

The Trial Cup Races.—The *Columbia* and *Constitution* have now completed the preliminary or tuning-up races, having sailed sixteen races, eight of which were won by the *Columbia*. The first races comprised a series of three off Newport, the first of which was sailed on the 5th of July. The two first were won by the *Constitution* in such a decisive manner as to inspire the hope that she was a much faster boat than the *Columbia;* but the wind was light and fluky, and yachtsmen felt that it would require trials under different conditions to establish the merits of the new yacht. The third race was won by the *Columbia*, and was sailed in a better breeze than either of the others. The *Independence* also took part in these races, and was badly beaten in the two first ones; but in the third, despite an accident in the early part of the race, she was close up at the finish. This was the last race in which the *Independence* participated with the *Constitution;* but she and *Columbia* had two races off Newport, both of which were won by the *Columbia*. The last race was over a triangular course of 30 miles, and was sailed in 2 hours 51 minutes and 48 seconds, the *Independence* being 40 seconds later in elapsed time, and 1 minute and 11 seconds corrected time.

The subsequent races between the *Columbia* and *Constitution* were sailed in Long Island Sound, the last one being over the Seawanhaka Club course, on the 24th of August, and was won by the *Columbia*.

There now remain the trial races off Newport, under the auspices of the New York Yacht Club, the result of which will decide which yacht will be selected to defend the cup, provided, of course, there is wind enough for a fair test under average cup conditions. The races thus far have been sailed in very light airs.

The *Shamrock II* arrived at New York on the 17th of August, and has had several spins since her arrival. The general impres-

sion is that she is the fastest yacht that has ever challenged for the cup.

She was caught in a squall in the Solent the latter part of May and almost wrecked, due to the breaking of a backstay. The accident also served to disclose other weak points in her construction, and, as it was thought that she could not be prepared in time for the cup races, Sir Thomas Lipton asked for a postponement, which the New York Yacht Club granted.

A somewhat similar accident happened to the *Constitution* off Newport on the 4th of June, caused by the breaking of the starboard masthead spreader, and resulting in breaking her mast, an accident almost identical to that that happened to the *Columbia* two years ago. During one of the trial races in the Sound the *Constitution* struck bottom, but examination subsequently made did not disclose any injury to her hull.

OBITUARY.

COMMODORE THEODORE ZELLER, U. S. NAVY,

Formerly a Chief Engineer in the U. S. Navy.

Commodore Theodore Zeller, United States Navy, was born December 1st, 1823, in the City of New York, and was educated in the High School of the Reverend Dr. C. Todd, at Stamford, Connecticut, a first-class educational institution of that time, in which he had for classmate Charles T. Quintard, afterwards the distinguished Anglican Bishop of East Tennessee. The school-boy friendship then contracted between them was continued until the death of the Bishop, a few years ago, the latter always making Commodore Zeller's house his home when in New York.

After graduation, Mr. Zeller having a pronounced aptitude for mechanical engineering, learned it practically in the best shops of the New York of that date, becoming a thorough proficient. He had also become a skillful mechanical draughtsman and designer, serving in that capacity in the office of C. W. Copeland, at that time one of the most eminent mechanical engineers of the United States, and the designer of the machinery of our first large war steamers, *Mississippi* and *Missouri*, besides several smaller ones. On the completion of the *Missouri*, and on the recommendation of Mr. Charles H. Haswell, the first Engineer-in-Chief of the Navy, Mr. Zeller was appointed a Third Assistant Engineer in the Corps of Naval Engineers, June 15th, 1843, and assigned to duty on board that vessel. When the *Missouri* was destroyed by fire at Gibraltar, on the 26th of September, 1843, Mr. Zeller, whose heroic efforts to save her were highly appreciated by her captain, remained, by his orders, in charge of the wreck.

His next service was on board the United States steamer *Colonel Harney*, cruising in the Gulf of Mexico and in the estuaries of Florida and Louisiana for the protection of the live oak

reserved there by the Navy for the construction of its ships. On this duty he contracted a malarial fever, the effects of which lasted during his life and probably shortened it. He was ordered to the *Colonel Harney* July 20th, 1844, and was detached February 21st, 1846.

On the 23d of March, 1846, he was ordered to duty in the Bureau of Construction in the Navy Department, as Assistant to the Engineer-in-Chief of the Navy, Mr. Charles H. Haswell; that distinguished engineer being then engaged on the designs for the machinery of the large war steamers about to be constructed. He remained on this duty until October 23d, 1846, when he was examined and promoted to the grade of Second Assistant Engineer, February 17th, 1847.

On March 23d, 1847, Mr. Zeller was ordered to the steamer *Union*, at Washington, fitted with Lieutenant Hunter's submerged paddle-wheel, and was detached May 25th, 1847, the vessel having been found unfit for sea service.

On October 20th, 1847, he was ordered to the steamer *Iris*, as her Acting Chief Engineer. The vessel proceeded to the Gulf of Mexico, and formed part of Commodore Perry's squadron, remaining there and participating in all the naval operations during the Mexican war. This service was very arduous and very dangerous. During the passage of the *Iris* from New York to Vera Cruz, Mr. Zeller, owing to the sickness of his assistants, remained on watch the entire time, eating and sleeping in the engine room as best he could, for the very heavy weather and the poor construction of the hull and machinery of this purchased steamer required unremitting vigilance.

He was detached from the *Iris* December 18th, 1848, at the conclusion of the war, and was ordered, April 18th, 1849, to join the steamer *Massachusetts* as her Acting Chief Engineer. This vessel had been detailed for special service with a joint commission of Army and Navy officers to select a site for a navy yard in California, and sites for fortifications on the coasts of California and Oregon. The discovery of gold in California rendered obtaining white seamen impossible at any wages, and even natives of the Sandwich Islands, and of China, were had with difficulty

to make up a crew, none of whom could speak English. Mr. Zeller, with a canoe manned by Indians, examined and located various deposits of coal, and tested their heating values and other properties for naval purposes. During this cruise he was promoted to the grade of First Assistant Engineer, November 6th, 1849.

He was detached from the *Massachusetts* March 25th, 1853; and on the 18th of the following October he was ordered as the Senior Assistant to the war steamer *Saranac*. He made the Mediterranean cruise in this vessel, and returned in her to the United States June 26th, 1856. He was then examined and promoted to the grade of Chief Engineer, August 15th, 1856, his commission being dated back to June 27th, 1855.

On the 12th of August, 1857, Chief Engineer Zeller was ordered to the *Saranac* for duty in the Pacific Ocean, and on November 19th, 1859, he was detached from that vessel and returned to the United States.

On the 31st of December, 1859, he was sent to Erie, Pennsylvania, to direct the repairs upon the machinery of the U. S. Steamer *Michigan*, including taking out the two old boilers and putting in two large Martin boilers. In this little town there were no facilities for doing such work, no machine shops, no derricks, etc., but Chief Engineer Zeller accomplished the whole with only the regular force of firemen and coal heavers attached to the vessel, and the tools, including a small lathe and planing machine belonging to her; nevertheless, the work was done in a very superior manner, though mostly by hand labor. The old boilers were taken out and replaced by the new ones with wonderful rapidity by means of a few beams of wood borrowed from an adjacent lumber yard, and a few screw-jacks belonging to the outfit of the engineer's department of the vessel.

On the completion of these repairs, he was appointed, November 19th, 1860, a member of a Board of Chief Engineers of the Navy, of which Chief Engineer Isherwood was the President, and which was directed by the Navy Department to make as complete a set of experiments as was practicable with the machinery of the *Michigan*, and, under the conditions for which it was con-

structed, to ascertain the relative economy due to the use of steam with the different measures of expansion lying between a very early and a very late cut-off. The admirable condition in which the machinery had been placed by Chief Engineer Zeller, and the intelligent zeal with which he seconded the President of the Board, contributed largely to the reliability and success of the experiments, which, in fact, created an era in steam engineering. After the completion of the experiments, he was ordered to duty on board the *Michigan*, employed in patrolling the lakes.

The civil war having now commenced, Chief Engineer Zeller was ordered, June 3d, 1861, to New York, to superintend the building of the machinery for the gunboats, sloops of war, iron clads, frigates, and other vessels, which were being constructed from designs furnished by the Bureau of Steam Engineering. This was a most arduous position, requiring great labor, professional knowledge, tact and devotion to the interests of the Navy. All these difficult requirements were most successfully met, and to the entire satisfaction of the Navy Department. During this time he was President of many Boards for various purposes, administrative, professional and experimental, in all of which his thorough practical knowledge, extensive theoretical information and efficient management were highly appreciated by the Navy Department.

On the 19th of May, 1863, Chief Engineer Zeller was appointed Fleet Engineer of the Eastern Gulf Squadron, with the rank of Captain, and he remained upon the staff of Rear Admiral Theodorus Bailey until September 1st, 1864, when the Department permitted him to return north to recruit his health, which had been much impaired by a violent attack of yellow fever. The headquarters of the squadron were at Key West, and the squadron itself was composed of a very large number of steamers, naval and purchased, employed in maintaining a rigorous blockade of the Confederate coast. The machinery of these vessels demanded incessant supervision and repairs.

The Fleet Engineer had to see that they were provided with the necessary coal, stores, material and personnel in their engineering departments, and that their machinery was kept in a

condition for maximum speed in the pursuit of blockade runners. He organized a complete repairing plant at Key West with which he maintained every vessel on its post, doing the heaviest repairs with the means he had created. No vessels were detached from the squadron and sent north for repairs to machinery while he was its Fleet Engineer. His services during this period were of inestimable value to the Navy, and were freely acknowledged by Rear Admiral Bailey.

As Fleet Engineer Zeller was too much needed by the Department to be allowed to remain a day longer off duty than was absolutely necessary for him to recuperate, he was ordered to report to Admiral David D. Porter, on the 5th of October, 1864, for duty as Fleet Engineer of the North Atlantic Squadron, the more northerly climate in which this squadron operated being considered as better for his health than the climate of Key West. He remained on this duty until the close of the war.

In the North Atlantic Squadron Admiral Porter reposed complete confidence in Fleet Engineer Zeller's ability and devotion to the service, assigning him a small steamer for his exclusive use, allowing him to cite the Admiral's name as authority without special authorization, and supporting him in all cases with the full weight of his power. Admiral Porter knew his man, and his confidence was well bestowed. The vessels of the North Atlantic Squadron, as regards their machinery and their engineer departments, were maintained in the highest state of efficiency, and the Admiral could always rely upon them as always ready for any service as far as their locomotion was concerned.

To these two squadrons was due the final and complete suppression of blockade running, which contributed so largely to the successful termination of the war, and which was due, as an indispensable primary condition, to the zeal, knowledge and ability of their Fleet Engineer, administratively as well as professionally, in maintaining the speeds of their vessels at the possible maximum, and in keeping every vessel constantly on its station.

That the foregoing statements relative to the value of Fleet Engineer Zeller's brilliant services are well within the truth, is

shown by the following official reports made, among others, by the admirals commanding both squadrons.

"*From the Secretary of the Navy to Fleet Engineer Theodore Zeller.*

"NAVY DEPARTMENT, WASHINGTON, *28 September, 1864.*

Sir: In forwarding to you a copy of a report from your late Commander, Acting Rear Admiral T. Bailey, relating to the very efficient and satisfactory manner in which you performed your arduous duties as Fleet Engineer of the East Gulf Blockading Squadron, the Department cannot withhold the expression of its sincere gratification and pleasure in communicating such reliable testimony of your character as an officer and services to the Government as expressed in this report.

"Very respectfully,

"GIDEON WELLES,

"*Secretary of the Navy.*

"CHIEF ENGINEER THEODORE ZELLER, U. S. Navy,

"New York."

From Rear Admiral Theodorus Bailey to the Secretary of the Navy.

U. S. FLAG SHIP *DALE.*

KEY WEST, *August 5th, 1864.*

"Hon. GIDEON WELLES, *Secretary of the Navy.*

"Sir: In availing myself of your permission to proceed north for the purpose of recruiting my health, I am desirous, before my departure, of placing upon the records of the Department some recognition of the very valuable services that have been rendered to the Government by Mr. Zeller, the Fleet Engineer.

"The Department is doubtless aware of the constant pressure that is brought to bear upon the commanding officer of a squadron to get vessels north on the plea that the boilers and machinery need extensive repairs, and, to meet this pressure on the part of interested parties, he has only the integrity and sound judgment of the Fleet Engineer and his *resisting power* to depend on. Mr. Zeller has done his duty so well in this respect that I am told he has incurred much ill-feeling on the part of those officers (I am sorry to say, not a few in number) to whose unpa-

triotic efforts to take their vessels north he has so persistently refused to lend himself, and in the same proportion he is entitled to the just recognition of the value of his services on my part.

"This officer is an enthusiast in his profession, an untiring worker and a devoted servant of the Government. In saying this in his behalf I am confident that I say no more than a year of unremitting labor in the interests of the Government (during which time he has personally superintended the machine shop and eighty machinists in addition to his other duties) has entitled him to receive.

"Respectfully,

"THEODORUS BAILEY, *A. R. Admiral,*

"*Commander of E. G. B. Squadron.*"

The above communication from Admiral Bailey having been referred to the Chief of the Bureau of Steam Engineering in the Navy Department, received from him the following endorsement:

"A personal and professional acquaintance of about twenty-five years enables me to fully endorse Admiral Bailey's opinion of Fleet Engineer Zeller, and to recommend him to the consideration of the Department as an engineer officer who has but few equals and no superiors for energy, practical skill, uprightness, and unswerving fidelity to the interests of his Government.

"B. F. ISHERWOOD,

"*Chief Bureau Steam Engineering.*"

From Admiral D. D. Porter to the Secretary of the Navy.

"NORTH ATLANTIC SQUADRON,

"U. S. FLAG SHIP *MALVERN,*

"HAMPTON ROADS, *November 6th, 1864.*

"Sir: I beg leave to submit to the Department the inclosed report, deeming it my duty to make known the indifferent manner in which work is done on machinery at the Philadelphia Navy Yard. The *Unadilla* has been there some time, and a very indifferent engineer would have found out the defects and remedied them. The vessel barely escaped being driven to sea, her

engines giving out entirely as she entered this port. I am fortunate at this moment in having so thoroughly an honest and independent a man as Chief Engineer Zeller to expose this neglect, and also fortunate in having a man who so well understands his business and is equal to the emergency.

"I am sir, very respectfully, your obedient servant,

"DAVID D. PORTER,

Rear Admiral.

"Hon. GIDEON WELLES, *Secretary of the Navy*,
Washington, D. C.

After the conclusion of the war, Chief Engineer Zeller was ordered to the Philadelphia Navy Yard, August 9th, 1865, as its Chief Engineer, remaining there until March 10th, 1869. He was next ordered to special duty at New York, July 8th, 1869, from which he was detached on April 11th, 1874, and ordered to report to Chief Engineer Isherwood for duty connected with the preparation of reports on the performances of U. S. steamers during the war.

In November, 1875, he was ordered, in conjunction with Chief Engineer Isherwood, to proceed to Europe and examine the dockyards, vessels and professional methods of the British, French and Italian navies; also the large private engineering establishments of Western Europe.

Early in the year 1877 he was ordered as a member of the Experimental Board which was permanently employed in experimenting with and reporting upon a great variety of steam engines, boilers, propellers and vessels, including all new inventions and improvements in machinery; also in experimenting with petroleum as a fuel, and with the great variety of lubricating oils derived from it; also in investigating the economic laws of steam and other fluids used for the production of power, various methods of forced draft for boilers, etc., etc.

October 6th, 1884, Chief Engineer Isherwood, the President of the Board, having been retired on reaching the age limit established by law, he was succeeded by Chief Engineer Zeller, who made important experiments and reports on the laws of

steering vessels by rudders and by pivoted propellers. On the completion of this service, having attained the age of 62 years, he was, December 1st, 1885, according to law, transferred to the list of retired officers of the Navy with the rank of Commodore.

After his retirement he continued to live in his residence in New York, of which city he had always been a citizen, and was actively engaged in professional work up to the commencement of his last illness, which was a lingering and painful one. He died June 30th, 1901, and was buried from Grace Church, Broadway. He was followed to the grave by the tears of all who knew him personally, and by the admiration of all who knew him professionally.

Commodore Zeller belonged to what was the old aristocracy of Manhattan Island—the *ancien regime* of our colonial period —a century ago. He was, by inheritance, "A Member of the Order of the Cincinnati," his paternal grandfather having been an officer in the Army of the Revolution and served through the war. He was polished in his manners, scholarly in his language, and refined in his address. He was a great conversationalist, and possessed fine taste in art, including music, together with many accomplishments. He was above the medium height, and was handsome in face and form. He was a most agreeable and instructive companion, unwearied in doing kind offices to others. He was devotedly attached to his profession, which always claimed his liveliest interest, and in which he was a past master. His temper was singularly even ; he had charity for all and censure for none. His society was always sought, and he was a favorite with all the commanding officers under whom he had served during his naval life. Of that life fourteen years and a half were spent at sea, and he was an efficient seaman as well as an engineer in the days when seamanship meant a great deal more than it does now, and engineering was an art as well as a science. He never complained of fortune, and bore the vicissitudes of life with equal calmness, whether they made for him or against him. His highest praise is his absolute honesty of thought and act. Under no circumstances would he, nor could he, swerve from the strict line of righteousness.